Reintroduction of Lower Columbia River Chum Salmon into Duncan Creek
2004 Annual Report

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Index

List of Tables

List of Figures

Forward

The National Marine Fisheries Service (NMFS) listed Lower Columbia River chum salmon as threatened under the Endangered Species Act (ESA) in March, 1999 (64 FR 14508, March 25, 1999). The listing was in response to the reduction in abundance from historical levels of more than half a million returning adults to fewer than 10,000 present day spawners (Johnson *et al.* 1997). Harvest, losses of habitat, changes in flow regimes, riverbed movement and heavy siltation have been largely responsible for the decline of Columbia River chum salmon (Johnson *et al.* 1997). The timing of seasonal changes in river flow and water temperatures is perhaps the most critical factor in structuring the freshwater life history of this species (Johnson *et al.* 1997). This is especially true of the population located directly below Bonneville Dam, where hydropower operations can block access to spawning sites, dewater redds, strand fry, cause scour or fill of redds and increase sedimentation of spawning gravels.

In Johnson *et al.*, (1997), only two chum salmon populations were recognized as genetically distinct in the Columbia River, although spawning has been documented in most lower Columbia River tributaries. The first population was located in the Grays River (RKm 34) (Grays population), a tributary of the Columbia River, and the second was a group of spawners in the mainstem Columbia River just below Bonneville Dam (RKm 235) adjacent to Ives Island and in Hardy and Hamilton creeks (Lower Gorge population). A possible third population of mainstem spawners, found in the fall of 1999, were located spawning above the I-205 bridge (approximately RKm 182), and is referred to as the Woods Landing/Rivershore population or the I-205 group. More recently, microsatellite DNA analysis reported by Small *et al.*, (2004) indicates that the I-205 group may be placed with the other Lower Gorge populations. However, this is based on only one year of sampling and more data is needed before a final determination can be made. Meyer *et al.*, (2003) has grouped Lower Columbia River chum salmon into three large groups named for their ecological regions: the Coastal, the Cascade and the Gorge. The Coastal group comprises those spawning in the Grays River, Skamokawa Creek and the broodstock used at the Sea Resources facility on the Chinook River. The Cascade group comprises those spawning in the Cowlitz (both summer and fall stocks), Kalama, Lewis, and East Fork Lewis rivers, with most supporting unique populations. The Gorge group comprises those spawning in the mainstem Columbia River from the I-205 Bridge up to Bonneville Dam and those spawning in Hamilton and Hardy creeks.

Response to the federal ESA listing has been primarily through direct recovery actions: reducing harvest, brood stocking for populations at catastrophic risk, habitat restoration (spawning channels) and flow agreements to protect spawning and rearing areas. Both state and federal agencies have built controlled spawning areas. In 1998, the Washington Department of Fish and Wildlife (WDFW) began a chum salmon supplementation program using native stock on the Grays River. This program was expanded in 1999 to include reintroduction into the Chinook River using eggs from the Grays River supplementation program. These eggs are incubated at the Sea Resources Hatchery on the Chinook River and the fry are released at the mouth of the Chinook River.

The recovery strategy for Lower Columbia River (LCR) chum salmon as outlined in Hatchery Genetic Management Plans (HGMP) has three main objectives. First, determine if remnant populations of LCR chum salmon exist in LCR tributaries. Second, if such populations exist, develop stock-specific recovery plans involving habitat restoration that includes the creation of spawning refugias, supplementation if necessary and a habitat and fish monitoring and evaluation plan. If chum salmon have been extirpated from previously utilized streams, develop reintroduction plans that utilize appropriate genetic donor stock(s) of LCR chum salmon, and integrate habitat improvement and fry-to-adult survival evaluations.

Third, reduce extinction risks to the Grays River chum salmon population by randomly capturing adults in the basin for use in a supplementation program and reintroduction into the Chinook River basin.

The Duncan Creek project was developed using the same recovery strategy implemented for LCR chum salmon. Biologists with WDFW and Pacific States Marine Fisheries Commission (PSMFC) identified Duncan Creek as an ideal upriver location below Bonneville Dam for chum salmon reintroduction. It has several attributes that make it a viable location for a re-introduction project: chum salmon were historically present, the creek is low gradient, has numerous springs/seeps, has a low potential for future development and is located close to a donor population of Lower Gorge chum salmon.

The Duncan Creek project has two goals: 1) reintroduction of chum salmon into Duncan Creek by providing off channel high-quality spawning and incubation areas, and 2) to simultaneously evaluate natural re-colonization and a supplementation strategy where adults are collected and spawned artificially at a hatchery. For supplementation, eggs are incubated and the fry reared at the Washougal Hatchery for release back into Duncan Creek. The tasks associated with reestablishing a naturally self-sustaining population include: 1) removing mud, sand and organics present in four of the creek branches and replace with gravels expected to provide maximum egg-to-fry survival rates to a depth of at least two feet; 2) armoring the sides of these channels to reduce importation of sediment by fish spawning on the margins; 3) planting native vegetation adjacent to the channels to stabilize the banks, trap silt and provide shade; 4) annual sampling of gravel in the spawning channels to detect changes in gravel composition and sedimentation levels. Schroder (2000) developed the tasks associated with the second goal of the recovery strategy for Lower Columbia River chum salmon and they are detailed in The Monitoring and Evaluation Plan for the Duncan Creek Chum Salmon Reintroduction Program (Duncan M&E). Four criteria are used to evaluate the success of this program: 1) the egg-to-fry survival rates in the renovated channels, 2) the survival of the eggs and fry used in the artificial rearing program in Duncan Creek, 3) the survival and spawning ground distribution of adult chum salmon produced from the spawning channels and the artificial rearing program, and 4) the straying rate of non-program chum salmon into Duncan Creek. The monitoring portion of the Duncan M&E includes documenting and monitoring the physical attributes of the channels. These physical attributes include, but are not limited to, gravel composition, sedimentation load, dissolved oxygen (DO) levels, vertical hydraulic gradients and water temperatures in the hyporheic zone, and flow.

Evaluation and Monitoring of Reintroduction Efforts

Currently, two methods of reintroduction are being simultaneously evaluated at Duncan Creek. Recolonization is occurring by introducing adult chum salmon from the Lower Gorge (LG) population into Duncan Creek and allowing them to naturally reproduce. The supplementation strategy required adults to be collected and artificially spawned, incubated, reared, and released at the mouth of Duncan Creek. All eggs from the artificial crossings at Washougal Hatchery were incubated and the fry reared to release size at the hatchery.

Part I: Adult Trapping at Duncan Creek

Introduction

Capturing returning adults from project releases and accurate population estimates are critical to evaluating the success of the different reintroduction strategies used at Duncan Creek. Three types of information are needed in order to produce survival estimates and to make assessments about where adults chum salmon produced from the Duncan Creek project spawn (Schroder 2000). First, accurate project origin fry numbers, both from hatchery releases and those naturally produced in the spawning channels. Second, all project fry produced must be marked for identification as adults. Finally, adults returning to local spawning areas will need to be sampled for these marks and accurate estimates of the spawning population must be made at all locations where adults are sampled for marks.

Methods

The Duncan M&E recommended an adult "V" weir trap and live box be used at the Duncan Creek dam structure to enumerate adult chum salmon that enter Duncan Creek (Schroder 2000). In 2003, operating a "V" weir trap at this location was not feasible for several reasons. Chief among these was fluctuating Columbia River water levels that could render the trap inoperable during critical times. The dam structure provides the only solid ground near the creek mouth where a trap could be placed. The dam at Duncan Creek consists of two main parts, a lake level control/fish passage side and a spillway side. Figure 1 is a picture of the dam taken in October of 2002 as the lake was being lowered to allow for fish passage. In the upper right side of the picture the spillway side of the dam can be seen. The left side of the dam is a concrete sluiceway with two vertical weir gates. These gates are closed to maintain the lake during the summer, then held in the raised position during the fall, winter and early spring to provide fish passage. This sluiceway provided the best location to place the adult trap.

Figure 1. Photo of the Duncan Creek Dam structure from the downstream side (Columbia River) during lake lowering, 2002.

Analysis of historic Columbia River water levels, measured on left bank 0.9 mile downstream from the Bonneville Dam powerhouse approximately 50 feet upstream from Tanner Creek (Rm144.5) (USGS Tanner Creek Gauge) during trapping months (October through December 1981-2002), showed river levels that would result in over eight feet of water depth in the sluiceway of the dam. A value of approximately 11.2 at this gauge results in the Columbia River water level equal to the bottom of the concrete sill at the sluiceway and allows for adult passage when combined with the outflow from Duncan Creek. Tanner Creek staff gauge levels of 11.5 and above are necessary for the Columbia River to inundate the floor of the sluiceway. Because of the relatively short trapping season and the importance of having the trap operational over the whole season, a trap was needed that could operate under a great range of water depths. WDFW biologist, working in cooperation with KPFF Engineering, designed a trap that would function similarly to the fish brails used at hatcheries.

The trap consists of three pieces and a lifting beam. The downstream piece acts as a fish barrier with a gated finger weir opening at the bottom (Figure 2 left side). The upstream piece acts as a fish barrier and trash rack (Figure 2 middle). The centerpiece consists of an open sided box with only a floor (Figure 2 right side) and ladder. Also visible in Figure 2 (right side) is the lifting boom used to raise and lower the trap box. The upstream and downstream pieces were attached to the walls of the sluiceway with just enough room for the trap box between them. What is not shown in these photos are the sets of plastic finger weirs (Neptune Marine Products Inc., Seattle, WA) that prevent adults from exiting the trap box once inside. When operating, the trap box sits in the floor of the sluiceway and the gate on the downstream weir is open to allow adults to pass through the finger weirs and into the trap box. To process adults in the trap box, the gate on the downstream weir is closed to hold fish in the trap box. If the Columbia River water levels are high (more than two feet deep in sluiceway), after the downstream gate is closed, the trap box can be lifted until the water depth over the bottom is shallow enough to process adults. The gate on the downstream weir also prevents adults from getting under the trap box when in the raised position. It is this ability to raise the trap box that allows for trap operation during high water events.

Figure 2. Pictures of adult trap installed at the Duncan Creek Dam, 2003.

Adults in the trap are captured either by either hand or by adult dip net. Adults were placed into an anesthetic bath (MS-222) until calm enough for sampling. Biological data collected from adults included: species, sex, marks/clips and fork length. In addition, on chum salmon adults mid-eye-to-hypural length, scale and DNA samples would be collected. Each adult was marked with two numbered Floy anchor-dart tags (Floy Tag & Manufacturing, Inc., Seattle, WA.) prior to release. Adults were allowed to recover from the anesthetic in the trap prior to release. Once recovered, adults were released through either of the two gated exits in the upstream weir. A staff gauge was attached to the trap box for monitoring water depth across the trap's floor.

Results

Trap installation took one week and was completed by September 30, 2003. Beginning on October 13, one weir gate was opened on the dam to begin lowering the lake. While the lake was draining, several hundred fish (predominately suckers, northern pike minnow and smallmouth bass) became trapped above the trap and had to be manually moved below the trap. Debris also accumulated on the upstream weir of the trap, necessitating manual removal as the lake was drained. Consequently, on October 15 the trap box was lifted, the upstream weir was removed and the downstream weir gate was lifted to allow fish and debris to pass through the trap area freely. Water from Duncan Creek only provided four to six inches of water in the trap box. As mentioned previously, the Columbia River water level measured at the Tanner Creek gauge, must be at or above 11.2 to approach the bottom sluiceway and produce a backwatering effect and increase the water depth in the sluiceway. Levels below this could result in stranding and killing adults in the trap. Ideally, the Columbia River water level would be at or above 11.5, which would provide unimpeded access to Duncan Creek through the sluiceway and remove any concerns about stranding adults in the trap. On October 24, a request to increase discharge to maintain water levels, at the Tanner Creek gauge, to 11.5 beginning November 1. It was made to the federal action agencies, through a System Operational Request (SOR) drafted and submitted by the Fish Passage

Advisory Committee (SOR 2003). Trap pieces were reinstalled on November 3 in preparation for adult trapping; however, the federal action agencies did not impellent this SOR. Without guaranteed minimum water levels, trapping could not begin. To prevent stranding adults, the entrance to the trap was kept closed until the necessary minimum water level was guaranteed to be met and maintained. Which did not happen until November 12 (Figure 3). With the upstream weir reinstalled, daily debris removal again became necessary.

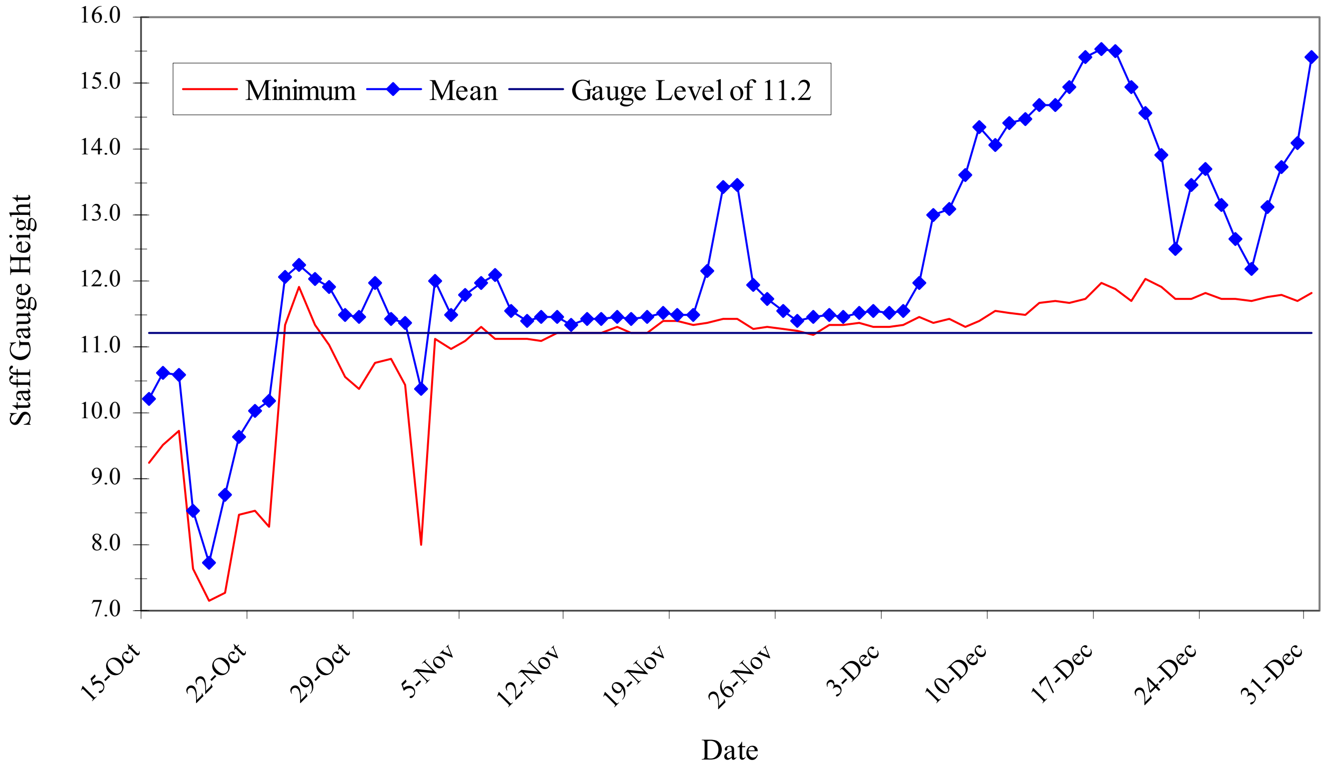


Figure 3. Daily mean and minimum Columbia River water level values October 15 through Dec 31, 2003, reported at the USGS Tanner Creek gauge.

On November 13, the plastic finger weirs were installed and the trap entrance was opened. Six adult coho were trapped over the next two days. Although several adult chum salmon were observed holding just below the dam and some were seen in the sluiceway, none entered the trap. On November 15, a wall of sand bags stretching from one side to the middle at the front, was placed into the trap box in an attempt to slow water velocities through the trap and provide some calm holding water. On November 17, it was discovered that enough small debris, primarily leaves, passed through the upstream weir to cause the plastic finger weirs to fail, several were damaged beyond repair. Leaves, along with large pieces of woody debris, were occluding the upstream weir and causing the lake to re-form between cleanings. These problems, combined with concerns that the presence of the trap and low Columbia River water levels was preventing chum salmon passage into Duncan Creek resulted in removal of the adult trap. The trap remained in place with the entrance closed, until its removal on November 20.

Discussion

The decision to design and install the adult trap this season and not wait until 2004 when the first marked adults would be returning proved very advantageous. In 2004, the trap will not be installed until after the lake has been lowered to prevent trapping lake resident fish above it and to allow most of the debris in the lake to exit. While the design was sound, the trap needs modification, so that the upstream weir has a gate allowing the trap to be in place without completely blocking passage during non-trapping periods. This gate could also be used to facilitate debris removal/passage. The plastic finger weirs proved too delicate for the flow and debris load at this trap. These should be replaced with "v" weirs constructed of heavy-duty material (possibly wood with metal bars or solid metal). Without adequate Columbia River water height to "back-up" Duncan Creek, water velocities in the sluiceway and through the trap appear to be too swift. Some of the coho adults were reported to appear very fatigued from holding in the trap box, though the sand bag wall placed on November 15 seemed to solve this problem. A flow defector was already in place on the upstream weir in anticipation of this problem but did not prevent it, and in fact exacerbated the debris problem. Three or four cross-weir panels, placed downstream of the trap in the sluiceway with openings on alternate sides, would decrease the water velocity through the trap. These cross-weirs would also back up the discharge from Duncan Creek providing more water depth in the trap box and sluiceway.

Part II: Duncan Creek Chum Salmon Hatchery Program

Introduction

The goal of the Duncan Creek chum salmon hatchery program at Washougal Hatchery is to preserve genetic diversity within the LG population and provide a source of chum salmon for reintroduction into Duncan Creek and other potential spawning sites. This is accomplished both by collecting sufficient numbers of brood stock to maintain genetic diversity, and by collecting those adults over the entire run period. The Hatchery Genetic Management Plan for Washougal Hatchery chum salmon calls for a minimum of 35 pairs to be spawned using factorial crosses to maintain genetic diversity. Historical run-timing records were consulted to calculate the number needed weekly to maintain natural run-timing. As in 2001 and 2002, 2003 brood stock were collected from known nearby spawning areas of the LG population. Methods used to spawn, incubate, and track various biological parameters from adult collection through fry emergence and ponding are detailed in (Schroder 2000). These methods are similar to those presented in the Summer Chum Salmon Conservation Initiative (WDFW and Point no Point Treaty Tribes 2000). Measurements of phenotypic traits collected on females used in the supplementation program will also provide the data needed to produce the predictive regression formulas of fecundity for estimating the egg-to-fry survival rates of females that spawned naturally in the channels. This is the third year of the hatchery program evaluation.

Methods

Adult Collection

Normalized brood stock collection curves were created using 2002 abundance data from mainstem spawning sites (Figure 4). Weekly brood stock collection goals were then calculated based on the seasons goal for brood stock. If weekly goals were not met, additional adults could be collected during the following weeks to meet the cumulative collection total.

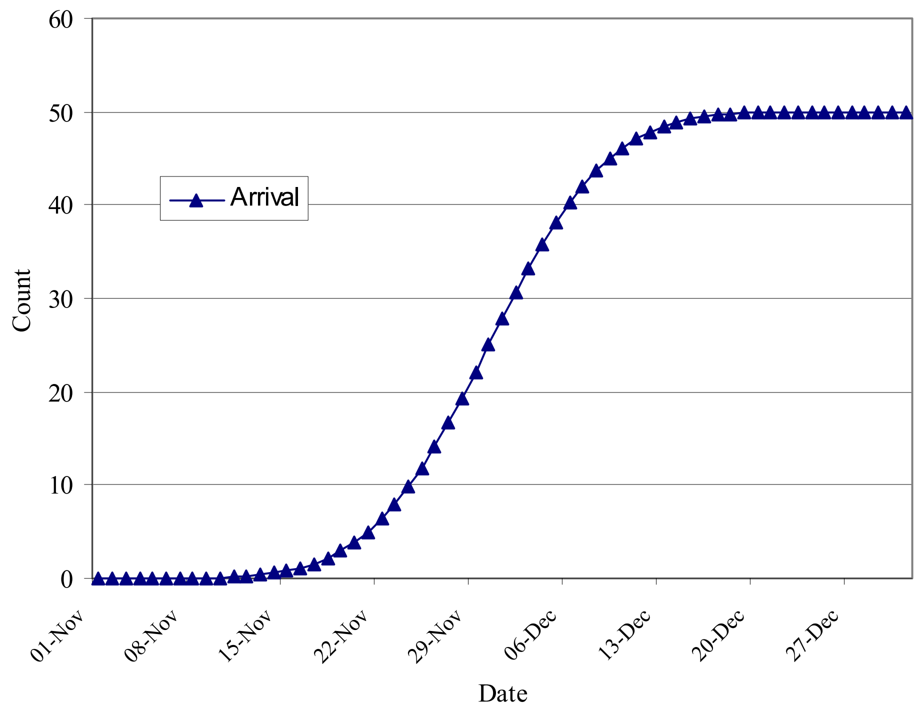


Figure 4. Normalized arrival timing for Ives Island area chum salmon from 2002, adapted from Rawding and Hillson (2003), used for a brood stock collection curve.

Personnel from WDFW and PSMFC collected adults from several known spawning locations using tangle nets and adult beach seines. Adults were captured as they staged and spawned in shallow water (< 10' deep). At the beginning of the season a 200' x 12' x 2" floating tangle net was used exclusively to capture adults, similar to that used in 2001 and 2002. Late in November, capture using a beach seine, 175' x 10' with ¼" mesh, was evaluated. Tangle nets catch adults by their maxillary bones and teeth which, while effective, is labor intensive to remove adults. This gear may also be selective for more mature adults and males. By contrast, the beach seine appears not to be selective and allowed for faster processing of adults out of the nets compared to the tangle nets. Tangle nets required that all adults be removed and placed into a second adult holding net before any fish could be processed. Using the beach seine eliminated this step since the adults could be left crowded up in the beach seine without fear of additional injury or mortality, thus increasing efficiency in the field. After only a few days of testing, the beach seine proved preferable and use of the tangle net was discontinued.

Criteria were developed for selecting adults to be used in the supplementation program. Females need to be in good condition, show no signs of redd digging activity (i.e. no wear on the lower caudle fin) and when checked for ripeness have a soft belly indicating a loose egg mass. Since the intention was to spawn all fish the day following collection, fully green females were intentionally excluded during brood stock selection. Males needed to be at least in fair condition and produce milt when checked for ripeness.

Adults selected for the supplementation program at Washougal Hatchery were placed into a fish tube. The fish tubes were three feet long sections of 10" diameter PVC pipe, perforated with several one and a half inch holes, and equipped with removable end pieces. Adults were marked to so that at spawning the date, time and location of capture could be identified. Tanker trucks transported fish, while they were still in the tubes, to the hatchery. Three tanker trucks were available for the project depending on the expected number of adults to be moved. They have capacities of 400, 1,500 or 2,000 gallons, and are equipped with an oxygen supply. The 400-gallon tanker truck was used exclusively during the 2003 season to transport adults.

Holding, Spawning and Rearing

Upon arrival at the hatchery, tubed fish were placed on the bottom in an adult holding pond. Fish were re-checked at the hatchery for spawning readiness based on the observed state of ripeness at time of capture. Once the number of ripe females was determined, the number of males needed to perform the factorial cross was calculated. Males were checked for ripeness, and the first available ripe males were used for spawning.

Protocols outlined by Schroder (2000) were followed to spawn, incubate and track various biological parameters from adult collection through fry emergence and ponding. These methods are similar to those presented in the Summer Chum Salmon Conservation Initiative (WDFW and PNPTT, 2000).

In summary, ripe females and males were killed with a sharp blow to the head and a gill arch was cut to bleed the females. Each fish was labeled by stapling a square of Rite-in-the-Rain paper with its assigned number to the opercle. Fish were numbered consecutively (F-1, F-2, F-3, M-1, M-2, M-3, etc) throughout the spawning season. Before any eggs were removed, each female's weight, fork and mid-eye-to-hypural (MEtH) lengths were recorded. A conditional assessment (ranging from excellent to poor) based on fin condition, scale loss and fungal infection was recorded for each adult. Females that may have already spawned (spent) or appeared to have partially spawned were also noted. Each female was wiped down to remove contaminants and water prior to egg collection. Eggs were extracted using a spawning knife and collected in a dry plastic bucket. Milt was collected only after all females in the cross had been spawned. Males were also wiped down prior to spawning and milt was expressed into a clean, dry container. Total egg mass weight (weight of green eggs minus ovarian fluid, 0.1 g accuracy) and mean green egg weight (0.01 g accuracy) were recorded for each female. Using these two values, an estimate of fecundity was calculated. Biological sampling of each fish included scale samples, pathogen samples, DNA samples and GSI samples. Five additional eggs were collected from each female to be water hardened and individually weighed to the nearest mg.

Factorial crosses were used whenever numbers of ripe males and females allowed. Each female's eggs were divided into the number of lots needed by weight. Milt was divided equally using a graduated syringe. No backup males were needed when performing factorial crosses since the males can back up each other, if a one-to-one cross occurred another male would be needed as the backup. After the gametes were mixed, water added, and backup milt applied, the eggs were allowed to sit for two minutes. Individual lots were then recombined, if needed, and placed into a Heath incubation tray. Eggs were exposed to a PVP solution for 60 minutes in the Heath tray before being moved into incubation racks. Each Heath tray was labeled with the females' number and spawn date.

After the eggs reached the eyed stage (~ 400 ^{o} C Temperature Units (TUs)), they were shocked, and non-viable eggs were removed and enumerated by hand. A total weight of eyed eggs was recorded and five sub-samples were weighed and hand counted to calculate estimates of total eyed eggs. These estimates were then used to calculate the mean and standard deviation. This mean number of eyed eggs, plus the number of non-viable eggs removed, provided a more accurate estimate of fecundity. Folded Vexar, which prevents yolk sac deformations and maximizes yolk material utilization rates, was placed in each Heath tray before returning the eggs to the trays after shocking and picking.

Fish liberated from a recovery program need to be marked for identification upon recovery (Schroder et al. 1995). Marking also allows comparisons to be made between different treatment groups. All fish released under this hatchery program were thermally marked. Thermal marks are created by manipulating temperatures during the stages between eyed and yolk absorption (Volk et al. 1990, 1994 and 1999). Each time the water temperature is dropped by 2-4^{o} C a distinctive black band is deposited in the microstructure of a developing otolith (Figure 5). Exposure to chilled water for periods of 8 to 48 hours will essentially create bar codes on the otoliths that can be read. The bar codes will be determined and a schedule for chilled water applications by personnel in the WDFW Otolith Lab. Hatchery personnel applied the treatments, and voucher samples were taken to determine mark quality and form.

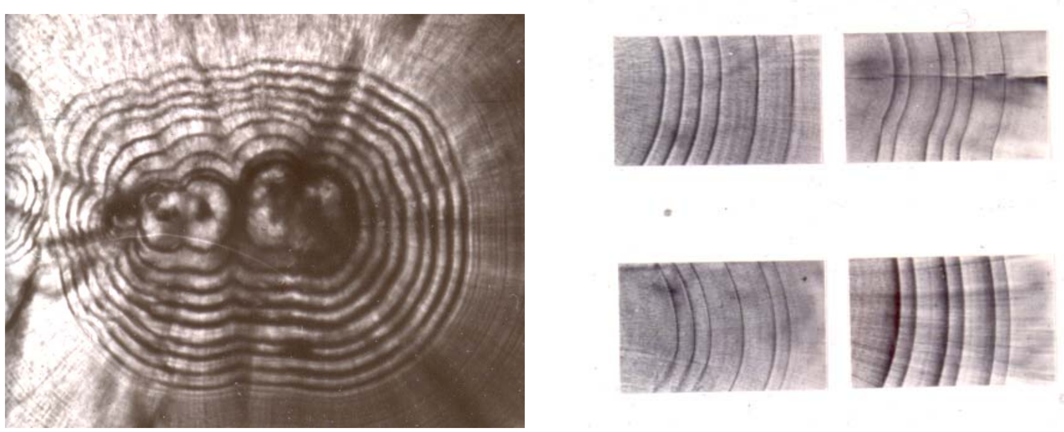


Figure 5. Photomicrographs showing the general appearance of thermally marked salmonid otoliths, from Schroder 2000.

At ~ 800 ^{o} C TU five to ten fry from each Heath tray were visually inspected to ascertain the width of yolk still visible on each fry. When only a small slit was observed, K_D values (Bams 1970) were calculated on 10 to 20 individuals from the tray:

$$K_D = (10 \sqrt[3]{\text{Wt in mg}}) / \text{Fork Length in mm}$$

When the average of these individual K_D values was ~ 1.9, the fry were ready to be ponded. K_D values were calculated again using five fry from each tray when they were ponded. Mortalities and abnormalities were enumerated and recorded for each female when the fry were ponded. These mortality numbers, combined with those removed at the eyed stage, were used to calculate egg-to-fry survival rates.

For chum salmon recovery projects at WDFW hatcheries, it is recommended that fed fry be reared to 1 - 1.5 grams or 50 - 55 mm in fork length before release. Such fry will likely realize significant survival advantages and not suffer any loss in their osmo-regulatory capacity (Steve Schroder, WDFW, personal communication) This size standard will be followed until data specific to a release location or stock indicates an alternative size may have an increased survival potential (Ames et al. 2000).

The fry were divided into rearing vessels and held at accepted rearing densities and flow index values. Fry were fed a semi-moist diet with no fines as mash diets are known to produce gill abrasions in chum salmon fry. Once the fish were actively feeding they received a daily ration of 3% of their body weight, spread out over the day with feeding occurring at least once every hour. Weekly weight measurements were taken to adjust the ration level. Feed size increased as the fish grew, but pellet size never exceeded one-fortieth of fork length of the reared fish. Mortalities were enumerated and removed daily. Rearing vessels were cleaned at least once per week. Several environmental parameters were measured and recorded during the rearing period with flow rates and DO levels measured and recorded weekly. Water temperatures were recorded twice daily (in the morning and after the last feeding) with a hand-held thermometer. Daily rainfall and ambient air temperatures were also recorded daily.

Feeding ceased two or three days prior to release, and fifty random fish from each rearing vessel were measured, fork length to the nearest mm, and individually weighed to the nearest 0.01g on the day of release. These data were used to produce mean weights, lengths, condition (K) values, coefficient of variation statistics for each measured parameter, and frequency distributions for lengths and weights.

Results

Broodstock Collection and Holding

A total of 79 adults (40 males and 39 females) were taken to Washougal Hatchery for spawning (Table 1). They were transported in the PVC holding tubes to the hatchery, where they were placed into an asphalt lined holding pond. No adults died while being held, three females were found to be not fully ripe (green) at spawning. Unfortunately, the first green female was killed prior to discovery. The other two green females were taken, along with two males, from the hatchery and placed into the spawning channels at Duncan Creek. Unfortunately it is possible for a female to “check ripe”, having a soft belly and giving a few eggs when squeezed, while the majority of the egg mass is remains firmly attached to the skein. Inclement weather, prevented brood stock collection activities on November 19, 2003. Another attempt was made on November 20, 2003, however, no ripe, un-spawned, females were found in the limited time available.

Table 1. Date of capture and origin of adults taken to Washougal Hatchery, 2003.

Date	Location	Number adult chum salmon seined	# Taken to Washougal Hatchery	
			Male	Female
11/12	Hamilton Slough	63	3	2
11/25	Hamilton Bay/Pocket	5	2	1
11/25	Hamilton Slough	13	2	0
11/25	Off mouth of Woodard Creek	38	7	3
11/25	Multnomah	166	0	7
12/3	Hamilton Slough	10	0	1
12/3	Hamilton Bay/Pocket	8	2	1
12/3	Off mouth of Woodard Creek	10	2	1
12/3	Multnomah	143	3	4
12/3	St. Cloud	50	5	4
12/10	Hamilton Slough	38	1	1
12/10	Multnomah	68	4	8
12/10	St. Cloud	51	9	5
	Total	663	40	38

Spawning

The spawning protocol detailed by Schroder (2000) was followed. Spawning occurred four times between November 13 and December 11 (Table 2). The number of females spawned on a given day ranged from two (the first spawn) to 12 (December 11). All adults were spawned within a day of capture. Males were selected for spawning based on the number of ripe females and a first into hatchery, first used basis. Table 3 details information on capture location/date and spawning date as well as biological data collected on males used for spawning.

The age composition of females taken to Washougal Hatchery was dominated by age-4 fish, 82.9% versus 17.1% for age-3 and 2.9% for age-5 (Figure 6). Similarly, the male age composition was dominated by age-4 fish, 94.7% versus 0.0% for age-3 and 5.3% for age-5 (Figure 6).

Fork lengths for age-3 females ranged from 624 mm to 744 mm, averaging 672.3 mm. Age-4 females ranged from 659 mm to 804 mm, averaging 732.1 mm, and the single age-5 female spawned had a fork length of 764 mm (Figure 7). No age-3 males were collected for spawning in 2003. Age-4 males ranged from 672 mm to 898 mm, averaging 782.6 mm, and age-5 males ranged from 808 mm to 813 mm, averaging 810.5 mm (Figure 8). Whole body weight for age-3 females ranged from 2,555.0 g to 5,091.0 g, averaging 3,382.7 g. Age-4 female whole body weight ranged from 2,741.0 g to 6,054.5 g, averaging 4,265.8 g, the single age-5 female whole body weight was recorded as 5,813.5 g.

The biological information collected on each female used in the supplementation program is presented in (Table 2). Fecundity estimates were made on females that had reproductive effort values (total egg mass/body weight) that were greater than 16%. These estimates showed that, at the green egg stage age-3 females had fecundities that ranged from 2,037 to 3,372, and averaged 2,630. The fecundities of four-year-old fish ranged from 2,051 to 3,825, and averaged 2,958 eggs. The one age-5 female had a reproductive value >16% and its fecundity was 3,530. An estimated total of 87,608 green eggs were collected during the spawning season.

Table 2. Summary of data collected on and from female chum salmon spawned, 2003.

Female #	Location of capture	Date of capture	Date of spawning	Factorial spawning, primary male listed first	Condition of fish at spawning	Whole body weight (g)	Fork length (mm)	MEtH length (mm)	Age	Green egg mass weight (g)	Mean green egg weight (g)	Estimated fecundity
F-1	Ives area	11/12/03	11/13/03	M-1, M-2, M-3	Excellent	4,938.0	756	617	4	492	0.326	1,788
F-2	Ives area	11/12/03	11/13/03	M-2, M-1, M-3	Excellent	5,015.0	738	583	4	944	0.367	3,048
F-3	Multnomah	11/25/03	11/26/03	M-4, M-5, M-6	Excellent	4,941.5	790	615	4	656	0.307	2,426
F-4	Multnomah	11/25/03	11/26/03	green	Excellent	4,081.5	722	595	4	green		
F-5	Multnomah	11/25/03	11/26/03	M-5, M-6, M-4	Excellent	5,089.5	768	610	4	746	0.286	2,711
F-6	Multnomah	11/25/03	11/26/03	M-6, M-5, M-4	Excellent	6,054.5	789	625	4	984	0.329	3,459
F-7	Multnomah	11/25/03	11/26/03	M-7, M-8, M-9	Excellent	3,575.0	688	540	3	656	0.285	2,615
F-8	Multnomah	11/25/03	11/26/03	M-8, M-9, M-7	Excellent	4,747.5	781	615	4	908	0.333	3,148
F-9	Multnomah	11/25/03	11/26/03	M-9, M-8, M-7	Excellent	3,239.5	674	540	4	686	0.302	2,662
F-10	Ives area	11/25/03	11/26/03	M-10, M-11, M-12, M-14	Excellent	3,249.0	688	550	4	404	0.265	1,759
F-11	Ives area	11/25/03	11/26/03	M-11, M-12, M-14, M-10	Good	4,148.5	727	575	4	784	0.267	3,452
F-12*	Ives area	11/25/03	11/26/03	M-12, M-14, M-10, M-11	Good	5,456.5	795	640	4	570	0.342	1,891
F-13	Ives area	11/25/03	11/26/03	M-14, M-10, M-11, M-12	Excellent	3,701.0	704	570	4	572	0.332	1,802
F-14	Multnomah	12/03/03	12/04/03	M-15, M-16, M-17	Good	3,844.0	719	583	4	506	0.312	1,790
F-15	St. Cloud	12/03/03	12/04/03	M-16, M-17, M-15	Excellent	5,091.0	744	607	3	906	0.293	3,372
F-16	St. Cloud	12/03/03	12/04/03	M-17, M-15, M-16	Good	5,407.5	793	641	4	656	0.323	2,281
F-17	Ives area	12/03/03	12/04/03	M-18, M-19, M-20	Excellent	3,380.5	690	560	4	576	0.232	2,968
F-18	Ives area	12/03/03	12/04/03	M-19, M-20, M-18	Excellent	2,555.0	656	540	3	382	0.263	1,715
F-19	Multnomah	12/03/03	12/04/03	M-20, M-18, M-19	Good	3,519.5	715	581	4	442	0.294	1,735
F-20	St. Cloud	12/03/03	12/04/03	M-21, M-22, M-23	Good	2,741.0	659	540	4	450	0.245	2,051
F-21	Ives area	12/03/03	12/04/03	M-22, M-23, M-21	Good	4,851.5	745	581	4	720	0.301	2,844
F-22	St. Cloud	12/03/03	12/04/03	M-23, M-21, M-22	Good	2,653.5	629	496	3	450	0.253	2,037
F-23*	Multnomah	12/03/03	12/04/03	M-24, M-25, M-26	Excellent	3,415.5	684	541	4	302	0.245	1,432
F-24	Multnomah	12/03/03	12/04/03	M-25, M-26, M-24	Good	3,054.0	670	529	4	510	0.245	2,471
F-25	Ives area	12/10/03	12/11/03	M-27, M-28, M-29	Good	3,930.5	720	585	4	466	0.290	1,846
F-26	St. Cloud	12/10/03	12/11/03	M-28, M-29, M-27	Good	2,691.5	624	498	3	466	0.249	2,107
F-27	Multnomah	12/10/03	12/11/03	M-29, M-27, M-28	Good	4,218.0	731	577	4	648	0.364	2,261
F-28	Multnomah	12/10/03	12/11/03	M-30, M-31, M-32	Good	2,851.0	660	523	4	452	0.215	2,451
F-29	Multnomah	12/10/03	12/11/03	M-31, M-32, M-30	Good	5,017.5	790	615	4	792	0.309	3,021
F-30	Multnomah	12/10/03	12/11/03	M-32, M-30, M-31	Excellent	3,854.5	727	577	4	410	0.209	2,318
F-31	Multnomah	12/10/03	12/11/03	M-33, M-34, M-35	Excellent	4,979.5	769	622	4	964	0.293	3,825
F-32	Multnomah	12/10/03	12/11/03	M-34, M-35, M-33	Excellent	5,980.5	804	632	4	956	0.339	3,271
F-33	Multnomah	12/10/03	12/11/03	M-35, M-33, M-34	Excellent	5,813.5	764	613	5	1,016	0.345	3,530
F-34	St. Cloud	12/10/03	12/11/03	M-36, M-37, M-38	Good	3,415.5	692	546	4	486	0.283	1,984
F-35	Multnomah	12/10/03	12/11/03	M-37, M-38, M-36	Excellent	3,730.0	693	552	3	698	0.278	2,871
F-36	St. Cloud	12/10/03	12/11/03	M-38, M-36, M-37	Good	4,586.0	731	582	4	718	0.280	2,664

* These fish were described as partially spawned out at the time of spawning.

Table 3. Summary of data collected from and on male chum salmon spawned, 2003.

Male #	Location of capture	Date of capture	Date of spawning	Condition at spawning	Fork length (mm)	MEtH (mm)	Whole body weight (g)	Age	Used as primary male with female #
M-1	Ives area	11/12/2003	11/13/2003	Good	866	635	7.6359	4	F-1
M-2	Ives area	11/12/2003	11/13/2003	Excellent	755	562	4.1700	4	F-2
M-3	Ives area	11/12/2003	11/13/2003	Fair	884	643	7.1660	4	----
M-4	Ives area	11/25/2003	11/26/2003	Good	804	620	5.8800	4	F-3
M-5	Ives area	11/25/2003	11/26/2003	Good	818	630	6.2250	4	F-5
M-6	Ives area	11/25/2003	11/26/2003	Good	817	615	6.1735	4	F-6
M-7	Ives area	11/25/2003	11/26/2003	Good	750	615	5.4350	4	F-7
M-8	Ives area	11/25/2003	11/26/2003	Good	794	610	6.0025	4	F-8
M-9	Ives area	11/25/2003	11/26/2003	Good	813	615	6.2625	5	F-9
M-10	Ives area	11/25/2003	11/26/2003	Good	760	580	4.6930	4	F-10
M-11	Ives area	11/25/2003	11/26/2003	Good	873	660	7.6505	4	F-11
M-12	Ives area	11/25/2003	11/26/2003	Good	817	620	6.6840	4	F-12
M-13	Ives area	11/25/2003	11/26/2003	Good	764	585	4.7345	4	----
M-14	Ives area	11/25/2003	11/26/2003	Good	692	530	2.8450	4	F-13
M-15	Ives area	12/03/2003	12/04/2003	Excellent	733	572	3.9475	4	F-14
M-16	Ives area	12/03/2003	12/04/2003	Excellent	672	530	2.9705	4	F-15
M-17	St. Cloud	12/03/2003	12/04/2003	Good	898	671	6.9105	4	F-16
M-18	Multnomah	12/03/2003	12/04/2003	Good	728	570	3.9625	4	F-17
M-19	Ives area	12/03/2003	12/04/2003	Fair	809	606	4.8385	4	F-18
M-20	Ives area	12/03/2003	12/04/2003	Good	864	648	7.7095	4	F-19
M-21	St. Cloud	12/03/2003	12/04/2003	Good	777	679	5.6175	4	F-20
M-22	St. Cloud	12/03/2003	12/04/2003	Excellent	678	536	3.2610	4	F-21
M-23	St. Cloud	12/03/2003	12/04/2003	Good	747	580	4.5340	4	F-22
M-24	Multnomah	12/03/2003	12/04/2003	Good	725	562	3.9800	4	F-23
M-25	Multnomah	12/03/2003	12/04/2003	Good	732	573	3.8960	4	F-24
M-26	St. Cloud	12/03/2003	12/04/2003	Good	735	566	4.5295	4	----
M-27	St. Cloud	12/10/2003	12/11/2003	Good	791	592	5.6505	4	F-25
M-28	St. Cloud	12/10/2003	12/11/2003	Good	748	574	4.7590	4	F-26
M-29	Ives area	12/10/2003	12/11/2003	Good	852	642	5.7280	4	F-27
M-30	St. Cloud	12/10/2003	12/11/2003	Good	777	583	4.8330	4	F-28
M-31	St. Cloud	12/10/2003	12/11/2003	Good	738	562	4.4455	4	F-29
M-32	St. Cloud	12/10/2003	12/11/2003	Good	808	614	5.8430	5	F-30
M-33	St. Cloud	12/10/2003	12/11/2003	Good	824	620	6.5940	4	F-31
M-34	St. Cloud	12/10/2003	12/11/2003	Good	719	551	4.1245	4	F-32
M-35	St. Cloud	12/10/2003	12/11/2003	Good	827	624	7.5825	4	F-33
M-36	Multnomah	12/10/2003	12/11/2003	Good	830	634	4.9935	4	F-34
M-37	Multnomah	12/10/2003	12/11/2003	Good	819	627	6.4785	4	F-35
M-38	Multnomah	12/10/2003	12/11/2003	Good	755	562	5.1370	4	F-36

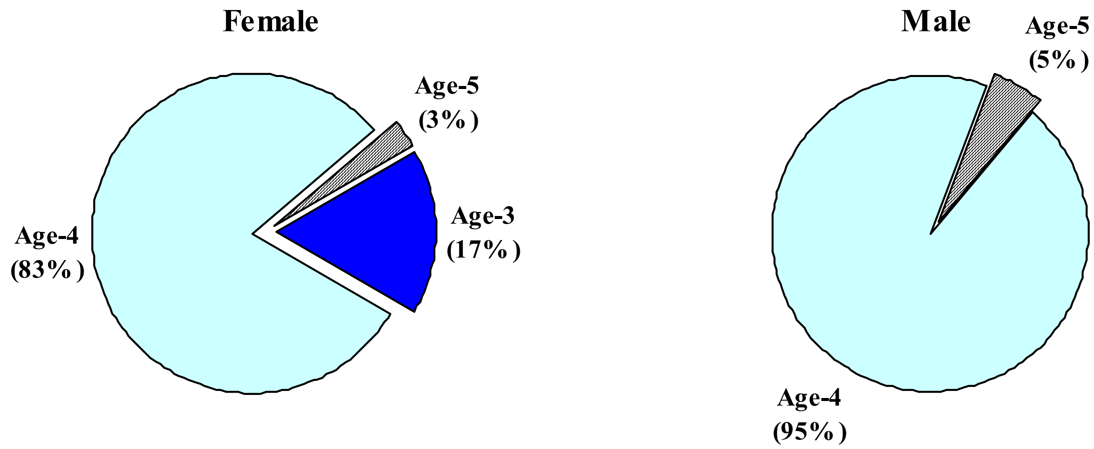


Figure 6. Age composition of adult chum salmon spawned at Washougal Hatchery, 2003.

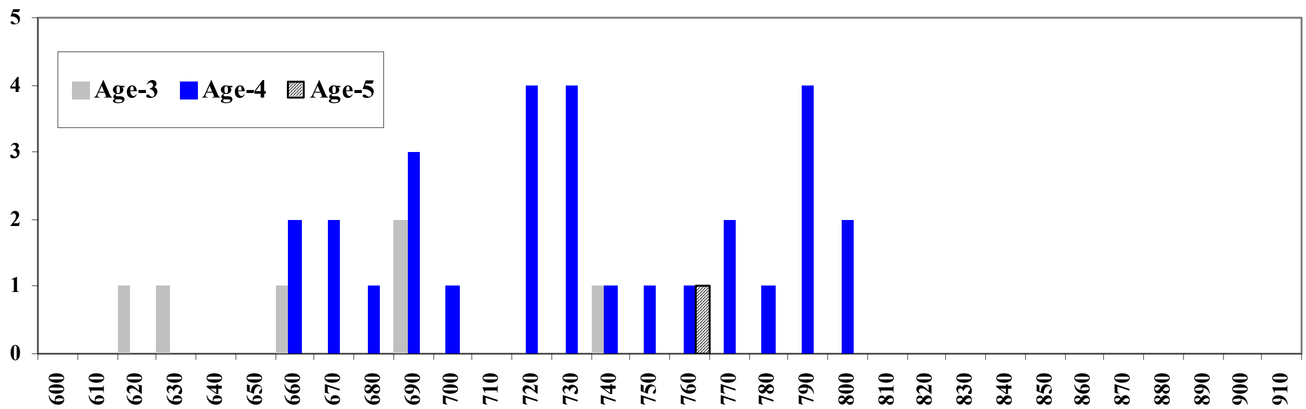


Figure 7. Fork lengths of female chum salmon spawned at Washougal Hatchery, grouped by age and 10 mm increments, 2003.

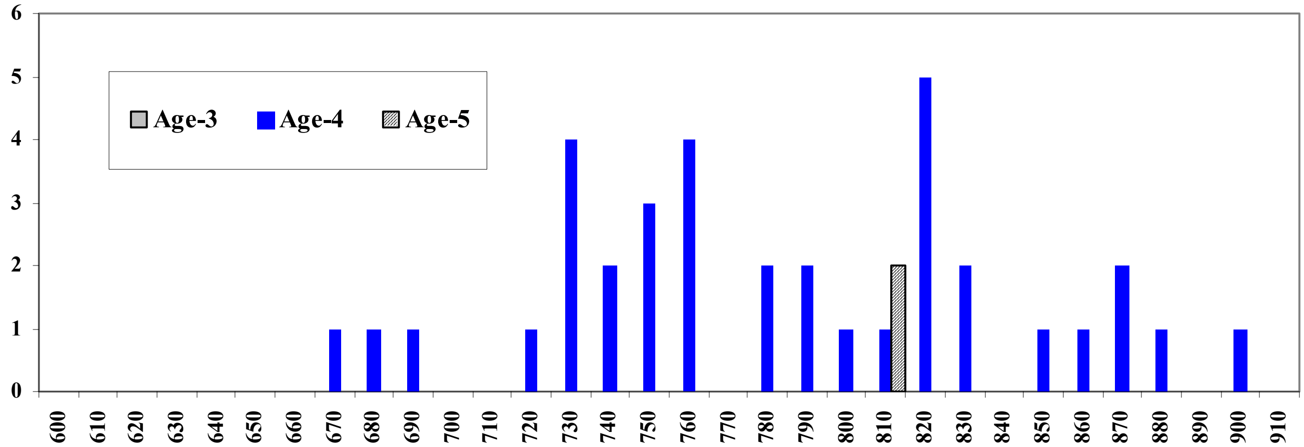


Figure 8. Fork lengths of male chum salmon spawned at Washougal Hatchery, grouped by age and 10 mm increments, 2003.

Incubation

All green eggs were disinfected in the Heath trays with a 60-minute treatment of iodophor Betadine before being moved into the incubation stacks. Flow through the Heath stacks was set at four gallons per minute and monitored by hatchery personnel. Daily formalin treatments, 15 min per day at 470 ml per minute, were applied from day two until just before the eggs hatched (minimum of five days) to prevent fungus (*Saprolegnia sp.*) growth in the trays. At around 400 TU ^{0}C, the eggs were shocked by pouring them from the trays into a bucket ½ full of water and then back into their trays. After waiting 24 hours, the eggs were hand picked to remove any mortalities and unfertilized eggs. A total of 5,316 non-viable eggs were recovered after shocking (Table 4). The number of non-viable eggs per female removed after shocking ranged from 16 to 991 and averaged 152.

The first thermal marks were applied to the otoliths prior to hatching. Five thermal events were applied to produce the pre-hatch mark of: | | | | | (narrow – narrow – narrow – wide). A post-hatching thermal mark of : | | | | (narrow – wide – narrow) was also applied. One day of ambient temperatures between treatments produced the narrow spacing and four days produced the wide spacing. Visualize these "|" as circles to get a good representation of the mark (Figures 5 and 9).

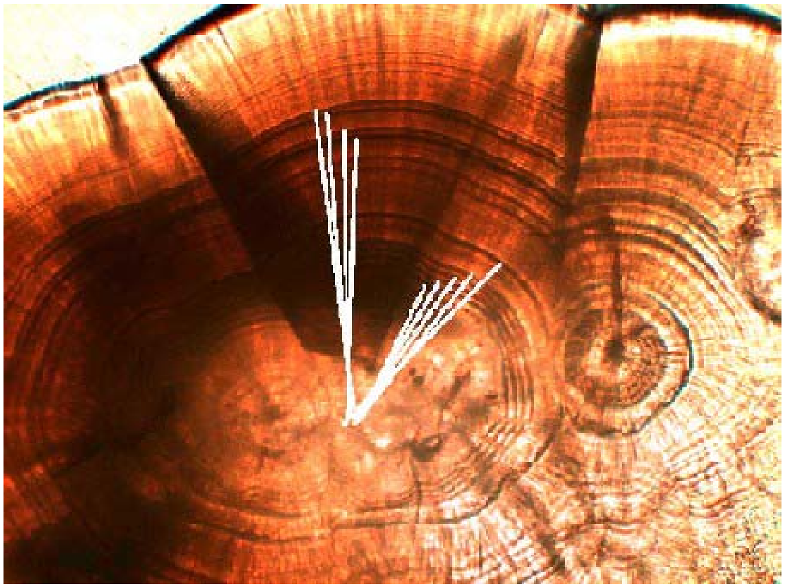


Figure 9. Photomicrograph showing the thermal mark created in 2004.

Fecundity estimates calculated after shocking and picking based on five samples of viable eyed eggs, including 95% C.I. and the CV of the mean, are reported in Table 4. Mean fecundity estimates for females with reproductive effort values >16% only, ranged from 1,894 to 3,666, averaging 2,751. Survival rates from green to eyed egg stage ranged from 58.38% to 98.89%, averaging 93.71% (Table 4).

The eggs began to hatch after they had accumulated approximately 600 TU ^{0}C. A total of 3,549 dead alevins, 135 non-viable eggs and 256 monstrosities were removed from the trays prior to ponding. The resultant loss totaled 3,940 (4.81%) from picked eyed eggs to ponding. Loss, by female, from the green egg stage to ponding is detailed in Table 5.

K_D values of fry from each tray at ponding are presented in Table 6. Individual fork lengths and weights were taken on five fry from each tray just prior to ponding. Fork lengths ranged from 33 mm to 42 mm, and averaged 37.7 mm. Individual weights ranged from 0.22 g to 0.50 g, averaging 0.36 g.

Table 4. Non-viable Eggs at shocking, mean live eyed egg estimates, 95% C.I. and C.V., fecundity and % survival rates from green to eyed egg stage, 2004.

Female	Non-viable eggs	Eyed egg weight	Mean live eyed egg estimate	Total eggs	95% C.I. High	95% C.I. Low	+/-	CV	Fecundity (base on sampling*)	Survival green to eyed
F-1	94	553.0	1,660	1,764	1665.98	1654.02	5.98	0.29	1,764	94.10%
F-2	27	1147.9	3,117	3,154	3146.16	3087.84	29.16	0.76	3,154	98.83%
F-3	34	717.4	2,240	2,279	2364.22	2115.78	124.22	4.48	2,279	98.29%
F-4	-----	-----	-----	-----	-----	-----	-----	----	-----	-----
F-5	101	824.9	2,762	2,868	2813.50	2710.50	51.50	1.51	2,868	96.30%
F-6	87	1115.9	3,283	3,375	3314.88	3251.12	31.88	0.78	3,375	97.27%
F-7	159	695.6	2,346	2,510	2418.39	2273.61	72.39	2.49	2,510	93.47%
F-8	86	894.5	2,637	2,728	2733.03	2540.97	96.03	2.94	2,728	96.66%
F-9	231	600.7	1,979	2,215	2025.37	1932.63	46.37	1.89	2,215	89.35%
F-10	102	441.7	1,587	1,694	1666.43	1507.57	79.43	4.05	1,694	93.68%
F-11	38	898.7	3,405	3,448	3434.97	3375.03	29.97	0.71	3,448	98.75%
F-12	230	568.7	1,644	1,879	1655.56	1632.44	11.56	0.57	1,879	87.49%
F-13	138	621.8	1,882	2,025	1902.50	1861.50	20.50	0.88	2,025	92.94%
F-14	20	566.5	1,771	1,796	1800.01	1741.99	29.01	1.32	1,796	98.61%
F-15	151	1022.1	3,396	3,552	3421.36	3370.64	25.36	0.60	3,552	95.61%
F-16	37	745.6	2,177	2,219	2241.97	2112.03	64.97	2.41	2,219	98.11%
F-17	86	677.6	2,875	2,966	2897.20	2852.80	22.20	0.62	2,966	96.93%
F-18	607	285.8	1,026	1,638	1137.55	914.45	111.55	8.79	1,638	62.64%
F-19	16	507.0	1,696	1,717	1728.71	1663.29	32.71	1.56	1,717	98.78%
F-20	154	478.7	1,894	2,053	1921.79	1866.21	27.79	1.19	2,053	92.26%
F-21	54	828.1	2,746	2,805	2779.68	2712.32	33.68	0.99	2,805	97.90%
F-22	40	514.6	1,981	2,026	1999.15	1962.85	18.15	0.74	2,026	97.78%
F-23	25	349.0	1,377	1,407	1418.35	1335.65	41.35	2.43	1,407	97.87%
F-24	144	570.4	2,308	2,457	2320.49	2295.51	12.49	0.44	2,457	93.94%
F-25	92	510.1	1,721	1,818	1761.61	1680.39	40.61	1.91	1,818	94.66%
F-26	49	517.9	2,002	2,056	2133.22	1870.78	131.22	5.30	2,056	97.37%
F-27	20	737.2	2,222	2,247	2306.64	2137.36	84.64	3.08	2,247	98.89%
F-28	146	496.6	2,214	2,365	2280.26	2147.74	66.26	2.42	2,365	93.62%
F-29	53	899.7	2,917	2,975	2955.94	2878.06	38.94	1.08	2,975	98.05%
F-30	949	283.4	1,338	2,292	1364.37	1311.63	26.37	1.59	2,292	58.38%
F-31	991	1083.7	3,666	4,662	3739.37	3592.63	73.37	1.62	4,662	78.64%
F-32	47	1056.8	3,169	3,221	3213.64	3124.36	44.64	1.14	3,221	98.39%
F-33	105	1160.5	3,457	3,567	3483.64	3430.36	26.64	0.62	3,567	96.92%
F-34	58	532.7	1,861	1,924	1889.43	1832.57	28.43	1.23	1,924	96.73%
F-35	40	787.7	2,778	2,823	2796.61	2759.39	18.61	0.54	2,823	98.41%
F-36	105	815.7	2,851	2,961	2884.81	2817.19	33.81	0.96	2,961	96.29%

* Fecundity calculated using mean number of live eyed eggs + dead eggs removed + five eggs removed at spawning for calculating water hardened green egg weight.

Table 5. Breakdown of loss by female from the green egg stage to ponding, 2004.

Female #	Loss at shocking	# Non-viable eggs at hatching	# alevin mortalities	Monstrosities removed	Total	% Loss
F-1	94	14	13	32	153	8.67%
F-2	27	12	0	7	46	1.46%
F-3	34	30	51	0	115	5.05%
F-4	----	----	----	----	----	----
F-5	101	44	61	20	226	7.88%
F-6	87	23	66	2	178	5.27%
F-7	159	0	35	4	198	7.89%
F-8	86	3	122	2	213	7.81%
F-9	231	0	1	6	238	10.74%
F-10	102	1	3	2	108	6.38%
F-11	38	0	0	2	40	1.16%
F-12	230	0	486	34	750	39.91%
F-13	138	0	249	4	391	19.31%
F-14	20	5	1	0	26	1.45%
F-15	151	0	299	2	452	12.73%
F-16	37	0	27	4	68	3.06%
F-17	86	0	8	2	96	3.24%
F-18	607	1	1	1	610	37.24%
F-19	16	0	3	5	24	1.40%
F-20	154	0	80	6	240	11.69%
F-21	54	0	3	5	62	2.21%
F-22	40	0	0	4	44	2.17%
F-23	25	0	2	1	28	1.99%
F-24	144	0	3	3	150	6.11%
F-25	92	0	39	4	135	7.43%
F-26	49	0	329	4	382	18.58%
F-27	20	0	243	4	267	11.88%
F-28	146	0	451	47	644	27.23%
F-29	53	0	18	7	78	2.62%
F-30	949	0	39	23	1,011	44.11%
F-31	991	0	174	3	1,168	25.05%
F-32	47	0	562	1	610	18.94%
F-33	105	0	0	4	109	3.06%
F-34	58	0	0	3	61	3.17%
F-35	40	0	179	4	223	7.90%
F-36	105	2	1	4	112	3.78%

Table 6. Average weights, fork lengths, date ponded and KD values at ponding by female, 2004.

Female #	# Fry sampled	Average weight (g)	Average fork length (mm)	Date ponded	K_D value
F-1	5	0.36	36.00	03/17/04	1.98
F-2	5	0.46	41.00	03/17/04	1.88
F-3	5	0.37	37.60	03/29/04	1.90
F-4	-----	-----	-----	-----	-----
F-5	5	0.34	36.40	03/29/04	1.92
F-6	5	0.38	37.40	03/29/04	1.94
F-7	5	0.35	36.60	03/29/04	1.93
F-8	5	0.39	37.60	03/29/04	1.94
F-9	5	0.38	37.20	03/29/04	1.94
F-10	5	0.34	36.80	03/29/04	1.89
F-11	5	0.35	37.80	03/29/04	1.87
F-12	5	0.40	36.60	03/29/04	2.01
F-13	5	0.38	37.20	03/29/04	1.95
F-14	5	0.44	40.00	04/05/04	1.90
F-15	5	0.36	37.20	04/05/04	1.91
F-16	5	0.40	39.20	04/05/04	1.88
F-17	5	0.29	36.80	04/05/04	1.79
F-18	5	0.37	38.80	04/05/04	1.85
F-19	5	0.39	39.40	04/05/04	1.86
F-20	5	0.32	35.60	04/05/04	1.92
F-21	5	0.39	38.80	04/05/04	1.89
F-22	5	0.35	37.20	04/05/04	1.89
F-23	5	0.34	38.20	04/05/04	1.83
F-24	5	0.35	37.60	04/05/04	1.87
F-25	5	0.36	37.40	04/12/04	1.90
F-26	5	0.32	36.20	04/12/04	1.89
F-27	5	0.40	38.80	04/12/04	1.90
F-28	5	0.29	34.80	04/12/04	1.90
F-29	5	0.39	39.00	04/12/04	1.87
F-30	5	0.23	33.80	04/12/04	1.81
F-31	5	0.39	38.80	04/12/04	1.88
F-32	5	0.39	38.20	04/12/04	1.91
F-33	5	0.43	39.80	04/12/04	1.90
F-34	5	0.38	39.40	04/12/04	1.83
F-35	5	0.32	36.40	04/12/04	1.88
F-36	5	0.37	38.40	04/12/04	1.87

Rearing

A total of 78,045 fry were ponded in three rearing troughs. Trough #1 received 27,213 fry, trough #2 received 22,781 fry and trough #3 received 28,051 fry. Trough #1 was split on 4/22/04, approximately 7,000 fry, into trough #4. Trough #3 was split on 5/10/04, approximately 8,000 fry, into trough #4. Flow rates were initially set at 25 gpm and adjusted by hatchery personnel as the fry grew to maintain the flow index within an acceptable range.

Three weight samples of 25 fry for each trough were collected each week to calculate daily feed amounts and to gauge when they would be ready for release. The fry were fed at a rate of 3% body weight per day. Feeding occurred at least eight times per day, approximately 1/8th of the daily ration every hour. A total of 5.24 pounds of on Bio-Oregon #0 crumb, 9.94 pounds of Skretting (formerly Moore Clark) Nutra #0 crumb and 12.5 pounds of Skretting Nutra #1 crumb starter feed was used over the 65-day rearing period. Fry sampling results are provided in Table 7.

DO levels in the troughs ranged from 11.1 to 13.0, averaging 12.0, during the rearing period. Water temperatures over the rearing period averaged 50 ^{0}F and 43 ^{0}F, afternoon and morning respectively. Mortalities were removed and enumerated daily. A total of 2,050 mortalities were removed from the four troughs between ponding and release, resulting in a survival rate of 97.4% from ponding to release.

Table 7. Results of fry sampling, 2004.

Sample Date	Trough #1 Average Size (g)	# Fish/lb	Trough #2 Average Size (g)	# Fish/lb	Trough #3 Average Size (g)	# Fish/lb	Trough #4 Average Size (g)	# Fish/lb
17-Mar	0.412	1,101						
24-Mar	0.433	1,047						
05-Apr			0.360	1,260				
07-Apr	0.391	1,162	0.352	1,289				
12-Apr					0.360	1,260		
14-Apr	0.438	1,035	0.364	1,248	0.364	1,247		
21-Apr	0.466	974	0.376	1,206	0.384	1,181		
22-Apr	0.466	974					0.466	974
28-Apr	0.612	741	0.524	866	0.516	878	0.659	689
05-May	0.794	571	0.678	669	0.642	707	0.889	510
12-May	1.122	404	0.979	463	0.883	514	1.075	422
18-May	1.407	322	1.208	376	1.113	408	1.470	308
20-May	1.410	322	1.252	362	1.207	376	1.539	295

Release

A total of 75,952 fry were released at night from the Skamania Landing boat ramp, located on the Columbia River immediately downstream from the mouth of Duncan Creek. The overall survival rate from green egg stage to release was 89.21%. All fry were liberated the evening of May 20, 2004. Results of the sampling done the day of release are reported in Table 8. The fry were dip netted from the troughs and placed into a 400-gallon tanker truck for transport to the release site. The truck was backed down the ramp and a flex hose attached to the tank transferred the fry into the water. The fish were monitored for 15-20 minutes for any immediate mortality and to ensure that they moved off into deeper water. Approximately 48 fry were killed during transport loading and less than 10 direct mortalities were observed at release.

Table 8. Average size (g), fork lengths (mm) and Kd values by trough on release day, 2004.

	Trough #1	Trough #2	Trough #3	Trough #4
# Released	19,049	22,057	19,804	15,085
Release Date	5/20/04	5/20/04	5/20/04	5/20/04
Average FL (STD)	57.08 (3.90)	55.02 (3.37)	54.62 (4.05)	58.60 (4.32)
Average Wt. (STD)	1.4096 (0.32)	1.2522 (0.23)	1.2070 (0.28)	1.5386 (0.36)
Average K_D (STD)	1.95 (0.03)	1.95 (0.03)	1.94 (0.06)	1.96 (0.03)

Discussion

The goal for hatchery brood stock collection was to maintain genetic diversity and timing by having representative collections. In 2003, 79 adult chum salmon were collected for artificial propagation at Washougal Hatchery. A normalized brood stock collection curve had been developed to guide weekly collection. The curve displayed in Figure 4 was the collection curve developed from 2002 data assuming stream residence time to be six days. Unfortunately, 2003 returning adults showed an earlier run timing and the number of adult chum salmon returning to the Ives Island area was lower. Fortunately, other areas did not experience the same decrease in returning adults (Rawding and Hillson, 2004, in prep). These two events led to a change in the primary brood stock collection area from the Ives Island area to the Multnomah spawning area in 2003. While this is a change from prior years, multidimensional scaling of microsatellite DNA analyses by Small (2003) grouped adults from the Multnomah spawning area with those from the Ives Island area. Brood stock were not collected from the I-205 spawning areas in 2003, spawners from these areas grouped away from the Ives Island adults in the same multidimensional scaling of microsatellite DNA analyses (Small 2003). Population data collected in 2003 will be used to refine the brood stock collection curve for 2004.

Chi^2 tests (Pearson's) were preformed to compare the age composition of adults used at the hatchery versus adults spawning naturally in the mainstem Columbia River, placed in the Duncan Creek spawning channels, adults spawning in Hamilton Creek and between mainstem spawning locations. Age composition data for adults spawning in the mainstem was a product from sampling done in conjunction with brood stock collection and population estimation work. A summary of this analysis is presented in **Appendix A.** Table 1. No significant differences ($P<0.05$) were found when comparing the age composition of adults used at the hatchery from a mainstem spawning location versus the age composition of all adults sampled at that mainstem spawning location. No significant differences ($P<0.05$) were found between the age compositions when mainstem spawning locations and adults collected from these sites were combined. No significant differences ($P<0.05$) were found when comparing the age composition of adults used at the hatchery versus those placed into the spawning channels at Duncan Creek. The only comparisons that returned P values <0.05 were for males when comparing the Ives area versus Hamilton Creek, Hamilton Creek having a higher percentage of age-5 males, and Ives areas versus St. Cloud for females, St. Cloud having a higher percentage of age-3 females.

Kolmogorov-Smirnov tests (K-S test) were used to test for differences in fork lengths of adults used at the hatchery versus adults spawning naturally in the mainstem Columbia River, placed in the Duncan Creek spawning channels and to adults spawning in Hamilton Creek. A summary of this test is presented in **Appendix A.** Table 2. For all locations where enough data was available (the K-S test requires at least 10 values in a data set) the only test that returned significantly different (P=0.042) when comparing adults used at the hatchery from a mainstem spawning location versus adults sampled and not used at that mainstem spawning location was for females at the Multnomah area. No significant differences (P>0.05) were found when comparing the fork lengths of adults used at the hatchery versus those placed into the spawning channels at Duncan Creek.

Rawding and Hillson (2004, in prep) reported population estimates of 1,844 (+/- 1,715) in the Ives area, 1,024 (+/- 59) for the Multnomah area and 180 (+/- 25) at St. Cloud. It should be noted that the Ives area estimate includes all or a portion of adults that spawned in Hardy and Hamilton creeks and the Hamilton spring channel. Total numbers of adults handled for hatchery brood stock collection at these areas was 185, 377 and 101 at Ives, Multnomah and St. Cloud respectively. Using these totals, the impact (percent handled) for hatchery brood stock collection was estimated to be 10%, 36.8% and 56.1% at Ives, Multnomah and St. Cloud areas respectively. Hatchery brood stock collection totals at these areas was 29, 26 and 23 adults at Ives, Multnomah and St. Cloud respectively. Using these totals, the impact (percent removed) for hatchery brood stock collection was estimated to be 1.6%, 2.5% and 12.8% at Ives, Multnomah and St. Cloud areas respectively.

Three females were found to be unripe at spawning. One was killed prior to discovery; the other two were taken, along with two males, to the Duncan Creek channels to spawn naturally. This resulted in 35 viable females spawned in 2003, compared to 93 and 23 in 2001 and 2002 respectively (Table 9).

Table 9. Numbers of females spawned, estimated egg take and percent survival between milestone stages for chum salmon spawned at Washougal Hatchery, 2001-04.

Year	# of females spawned	Estimated # of eggs taken	% Survival: Green to eyed egg stage	Eyed egg to ponding	Ponding to release	Green egg to release
2001-02	23	65,922	82.9	87.4	98.1	78.2
2002-03	93	244,156	92.5	98.3	98.1	90.3
2003-04	35	87,486	93.7	95.2	97.4	89.2

The low rate for green-egg to release survival in 2001-02 was a result of the total loss of one female's egg production and an overestimation in the calculation for the number of green eggs per female at spawning. When formulating the 2001-02 predictive regression formulas, the fecundity estimate at the eyed egg stage was on average 87% of the fecundity estimate recorded at the green egg stage (live and dead eggs combined). This difference should not be more than two or three percent. This error was likely due to incomplete draining of ovarian fluid before weighing the green egg mass. For 2002-03 and 2003-04, fecundity estimates at green and eyed egg stage differed by less than one percent. A total of 3,940 mortalities were recovered between the eyed egg stage and ponding, resulting in a mortality rate of 4.8%, this compares to rates of 1.8% and 12.6% in 2002-03 and 2001-02 respectively. A total of 2,050 mortalities were recovered between ponding and release, yielding a survival rate of 97.4% from ponding to release. This rate is lower than the rate recorded in both prior years. A large portion of the mortality during this time-period came from two troughs, #1 and #2. A state certified fish pathologist was called to examine the fry and could not find any pathological reason for the increase in mortality. However, the pathologist did note a larger than expected number of "pin-heads" and "drop-outs". This observation echoed what was seen in the growth rates of the fry during weekly sampling. In 2003, fry were reared at higher densities and grew at a faster rate (# fry per pound decreased at a rate of about 250 each week) so density was not considered a factor in this mortality increase or slow growth. What was different in 2004 was the type of food fed. In response, with agreement from the pathologist, the feed type was changed from Bio-Oregon starter feed to Skretting Nutra starter feed. After the feed type was changed, mortality decreased and growth rates increased.

Despite minor problems, the Washougal Hatchery operations for chum salmon were very successful in 2003-04. The goal of collecting 30-50 females for the formulation of the predictive formulas needed for fecundity estimates of channel spawning females was met, green-egg-to-release survival was close to 90%, and fry were above recommended size, average weight and fork length, at release. Sampling and data collection was more precise and complete in 2003-04 with the addition of individual green egg weights (mg). As in prior years, the fry from the hatchery were not ready for release until May. Ideally, these fry would be ready for release at the same time as fry naturally produced in the channels are outmigrating, which occurs in April. If the intent is to continue using Washougal Hatchery facilities to rear artificially spawned juveniles, and matching the natural migration timing is important, a heated water system may be necessary to duplicate temperatures that naturally-produced fry experience in the channels.

Potential problems identified and detailed last year (Hillson 2003) relating to incubation and rearing space limitations at Washougal Hatchery still exist, and one worsened in 2004. A new system of poles and cables was installed during late winter to replace the existing bird netting super-structure that was damaged during winter snowstorms. This new system prevents placement of the rearing troughs into the raceway via a boom truck. As a result, the rearing troughs had to be placed alongside the raceway this spring. The inflow to the raceway was plumbed into a manifold to provide water and a drain system was built to get the effluent back to the drain sump. While this system worked, the increase in head differential due to moving outside the raceway meant that only sufficient inflow for four troughs could be maintained. An additional pump, normally reserved as a backup, was needed to maintain inflow to the rearing troughs once the other raceways were put into production. This problem must be addressed if Washougal Hatchery is to be part of any future large scale salvage plans for chum salmon. Four rearing troughs will only provide space for the fry of approximately 45 females.

Part III: Monitoring the Physical Attributes of Spawning Channels

Introduction

Historically, Duncan Creek was an important spawning area for chum salmon. After the construction of a pond in the lower portion of Duncan Creek in 1961, chum salmon abundance in the creek declined. In 1999 chum salmon were listed under the ESA, and recovery efforts increased. Spawning channels have been used successfully to establish and re-establish chum salmon populations (Bonnell 1984; Cowan 1984). After preliminary investigation by WDFW, PSMFC, and KPFF engineering, it was determined that a spawning channel in Duncan Creek could be successful if passage conditions at the pond outlet could be modified and pond levels managed to assist in migration. The original chum salmon spawning area in Duncan Springs was rehabilitated in October 2000, and a chum salmon spawning channel was constructed at this site in October 2002, by KPFF engineering. See Appendix A of Hillson (2002) for details of the channel's engineering and construction.

Continued monitoring of physical attributes of the spawning channels is an important component of the reintroduction program. Monitoring the environmental conditions will identify factors responsible for survival/mortality rates. Salmonid research demonstrates that extremely high mortality rates, up to 99%, can occur between fertilization and emergence (Wickett 1952; Hunter 1948; Neave and Foster 1955). Several studies have attempted to identify mortality causes during the period of incubation (see Wickett 1954; Wickett 1958; Alderdice *et al*. 1958; McNeil 1962; Cooper 1965; McNeil 1966, 1983; Loptspeich and Everest 1981; Alexander and Hansen 1986; Kondolf *et al*. 1991; Marten 1992; Geist and Dauble 1998; Argent and Flebbe 1999; Baxter and McPhail 1999). Temperatures of less than 36 ^{o}F during the spawning period can delay spawning and increase egg retention rates (Schroder 1973; Koski 1975). Relatively low or high temperatures prior to blastopore closure have also been shown to cause high mortality rates in salmonid embryos (Brannon 1987; Tang et al. 1987; McNeil and Bailey 1975). Several researchers have linked embryonic salmonid survival to the composition of spawning gravels, specifically the proportion of materials ≤ 3.3mm, fines and sand. Materials of this size can reduce permeability of the gravel, thus reducing oxygen exchange and intra-gravel flows (McNeil and Ahnell 1964; Koski 1966, 1975; Tagart 1976, 1984; Witzel and MacCrimmon 1983). Lotspeich and Everest (1981) proposed that the geometric mean of the spawning substrate particle (D_g) be divided by its associated standard deviation (S_g) to produce the "Fredle Index" (f_i). Chapman (1988) plotted Fredle Index values against egg-to-fry survival rates from four independent studies and found that survival rates increased as the Fredle value rose from one to four. The gravel "recipe" placed in the Duncan Creek spawning channels was expected to yield a fredle index value of 5.2 (Table 10).

Table 10. Composition of gravel to be placed in the Duncan Creek Spawning Channels.

Diameter of gravel	Expected volume (%)
4 –6 inch rock	2
2.5 – 4 inch rock	13
1 - 2.5 inch rock	35
0.75 –1 inch rock	35
0.375 – 0.75 inch rock	10
No. 4 – 0.375 inch rock	5
No. 10 – No. 4 material	0

Environmental factors often cited as having the greatest influence for incubation survival include: redd superimposition, scouring and gravel fill as a result of dynamic river flows, high or low water temperatures during critical incubation times, sedimentation or high levels of sand and silt in the spawning gravels, low seepage velocity and/or low dissolved oxygen levels in the interstitial spaces, dewatering of eggs or alevins, and the presence of intra-gravel predators. Of the factors identified above, gravel composition, water temperature, low seepage velocity (vertical hydraulic gradients) and/or low DO levels in the interstitial spaces are of primary concern in the Duncan Creek channels. Monitoring these environmental conditions will provide the information needed to characterize the conditions in the channels between fertilization and emergence. The other environmental factors identified, while important, should not be of great concern since this spawning area is in a spring channel and protected from extreme environmental variation. Factors such as redd superimposition and egg retention due to overcrowding can be controlled by maintaining densities of females at levels that ensure each female has at least three square meters of spawning area and placing the fish into the channels over a two or three day period (Schroder 1973), but this should not be a factor until adult abundance in the channel approaches capacity.

Annual sampling of the gravel in the channels will document changes in gravel composition, with emphasis on material less than 3.3 mm in diameter, such as sands and fines. If annual gravel monitoring documents the Fredle Index decreasing over time, or percentage of fines less than 0.85mm increasing, this could trigger gravel-cleaning efforts. Piezometers will be used to monitor and document water temperatures, seepage velocities (vertical hydraulic gradients) and DO levels present in the hyporheic zone.

Gravel sampling was scheduled to be done prior to introducing fish into the channels during fall of 2001. However, due to limited resources it was not done until late in the summer of 2002, after the first year of use. Lake levels remained high and gravel sampling was limited to the upper two-thirds of one channel. In 2003, gravel sampling was scheduled for the last week of May after fry trapping had ceased. However, flows on the Columbia River increased and flooded the channels prior to sampling. By agreement, the gates controlling lake formation were closed on June 1, preventing any gravel sampling in the spring of 2003. Flooding the channels is intentionally done to limit recolonization of non-indigenous plant species, specifically reed canary grass (*Phalaris arundinacea)*. As a result, gravel samples were collected twice during this reporting period, in the fall of 2003 once the lake level was dropped and again in the spring of 2004 after fry trapping ceased.

Methods

The protocol for selecting and analyzing gravel samples from Schroder (2000) will be followed. This calls for twenty gravel core samples to be collected from the area above the weirs in each channel, 60 samples total. Two channels located above the south weir are sampled independently (Figure 10). The south channel was sampled to its confluence with the middle channel, and the middle channel sampled to the weir. During spring 2004 sampling, the decision was made to not examine the south channel because no adults have used this channel. Sampling locations were determined by measuring center channel length to the weirs, south channel measured to confluence with middle. The channels are then divided into four equal sections, and these sections divided into ten equal plots. A random number generator was used to select five plots in each section (four sections, with five sampled plots each, resulting in 20 samples per channel). Section and plot boundaries were marked with survey flags inserted into the gravel. All samples were taken as close to the center of the channel as water depths allowed, on the plots downstream boundary.

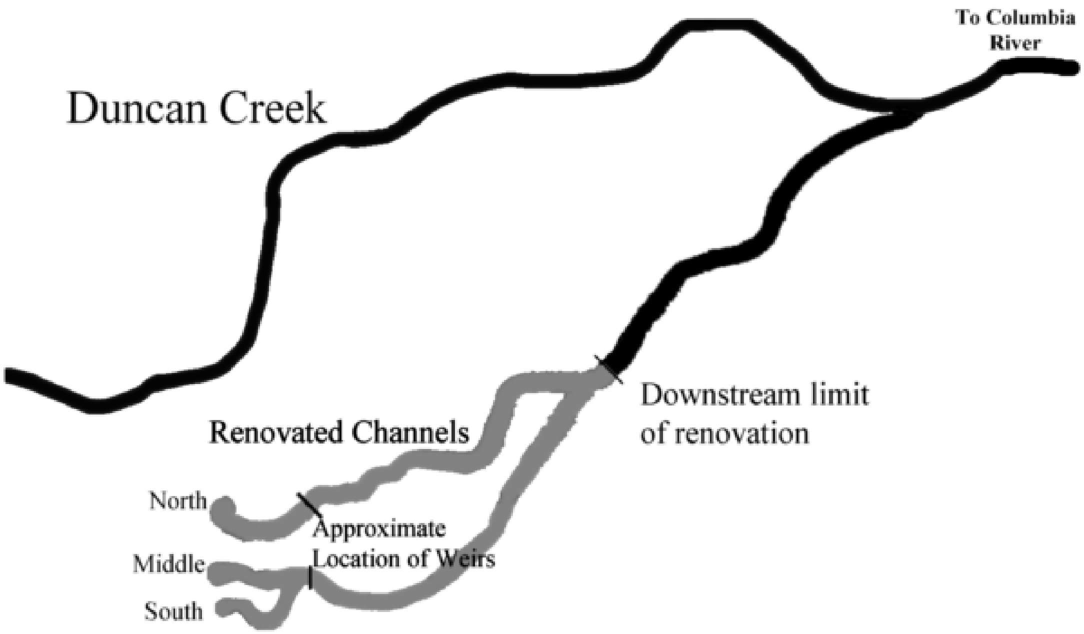


Figure 10. Diagram of Duncan Creek and the renovated spawning channels.

A McNeil Sampler (McNeil and Ahnell 1964) was used to collect standardized core samples. The sampler is inserted into the substrate approximately six inches. All material inside the sampling cylinder, six inches deep by four inches in diameter, is removed by hand and placed in the larger cylinder. Fines suspended in the water column by excavation activities are collected by slowly inserting a plunger/gasket to the bottom of the sampling cylinder. This plunger has a one-way-flapper valve to allow it to be inserted without driving the water and suspended materials out into the surrounding gravel. Once the plunger is at the bottom of the sampling cylinder, it is pulled up approximately ½" to form a seal with the gasket. Then the sampler, gravel and water retained inside, is lifted from the streambed and placed over a five-gallon plastic pail. The contents of the sampler are then released into the pail by allowing the plunger to fall. Gravel remaining in the large cylinder of the sampler is poured into the pail; additional water is used if needed to rinse all materials from the sampler. When the water depth in the channel is approximately ≥ 12", additional pails are needed to hold the complete sample. Figure 11 is a composite of four pictures taken during the summer of 2002 gravel sampling. Arranged clockwise from upper left, these are: 1) removing the gravel from inside the sampler core, 2) the sampler being placed on a collection bucket, 3) looking down into the sampler (with gravel and water inside) after the plunger has been released and, 4) pouring the remainder of the sample into the collection bucket.

Figure 11. Taking a gravel sample with a McNeil sampler.

In 2002 samples were dried and processed through a series of nine Tyler sieves (76.1 mm, 50.0 mm, 25.0 mm, 12.5 mm, 9.51 mm, 6.35 mm, 4.76 mm, 2.36 mm and 1.70 mm) using a Tyler sieve shaker. The weight of materials retained on each sieve and the solid bottom pan were recorded. These weights were then converted to weight fractions (%) of the sample. Samples taken in fall of 2004 and spring 2004 were dried and will be processed through nine Tyler sieves (75.0 mm, 50.0 mm, 25.0 mm, 12.5 mm, 6.3 mm, 4.75 mm, 2.00 mm, 1.7 mm and 850 µm). Values for D_g will be calculated for each sample from the sieve data by the method of moments, according to Shirazi et al. (1981):

$$D_g = d_1^{w1} \text{ x } d_2^{w2} \text{ x } \ldots \text{ x } d_n^{wn} \qquad (1)$$

Where $d_1 \ldots d_n$ = sieve size (mm) $1 \ldots n$; and $w_1 \ldots w_n$ = percent of sample weight retained on sieve $1 \ldots n$.

Values for S_g will be calculated using the "non-biased" or "n-1" method:

$$S_g = \sqrt{(n\sum x^2 - (\sum x^2))/n(n-1)} \qquad (2)$$

A Fredle Index will then be calculated based on these samples (Sowden and Power 1985):

$$f_i = D_g / S_g \qquad (3)$$

Rood (1998) provided a formula for calculating the precision (I) at which a particular fraction of the gravel was collected:

$$I = DF/F^* \qquad (4)$$

Where, F* is the mean percentage of a particular fraction and DF is the confidence interval around that mean percentage. Applying this formula to the data collected allows precision estimates to be calculated for particular gravel fractions and determine if 20 samples per channel was adequate to provide the desired precision rate ($I \leq 10\%$).

Water temperatures were continuously monitored using 18 Onset® Optic StowAway® data loggers, set to record the temperature every two hours. The data loggers were placed into a section of two-inch diameter perforated PVC pipe six to eight inches long. Six of these units were attached to sections of ¾" rebar driven into the gravel substrate to anchor the data logger. Two were placed into each channel, one at the top and the other just above the weir or confluence, at mid-water depth. The remaining 12 were attached to lengths of eighth inch stainless cable and buried 12" in the channel substrate, four per channel evenly spaced down the channel's length to the weir or confluence. The other end of the cable was attached to ¾" rebar driven into the bank as anchors. Data from these recorders were recovered at the end of the season after fry trapping ended.

Mini-piezometers were placed at the top and then every 50' down the length of each channel to the weir or confluence to monitor DO levels, vertical hydraulic gradients (VHG) and water temperatures in the hyporheic zone. The mini-piezometers were placed at approximately mid-channel and driven 12" into the substrate so that intra-gravel water could be sampled at the same depth as eggs were expected to be deposited. Once adults are placed into the channels, measurements of DO and temperature (three readings at each mini-piezometer to calculate a mean value) would be recorded every two weeks until fry emigration was complete. Mid-water temperature and DO values were also recorded outside the first and last piezometer in each channel when values inside the piezometers were recorded. Schroder (2000) recommends VHG values to be determined three times over the course of the season; once at the end of spawning, again at the end of December when typical winter flows are occurring and finally at the end of the fry emigration in the spring. Because the end of spawning normally occurs around the end of December, these two samplings times normally are combined. VHG values are determined using the following formula:

$$VHG = \Delta h / L \qquad (5)$$

Where Δh is the measured difference in water elevation between the inside of the piezometer and the outside stream water surface. Calculated as h_s-h_1, where h_s is the distance from the top of the piezometer to the stream surface and h_1 is the distance from the top of the piezometer to the water surface inside the piezometer. In the formula L equals the distance below the streambed to the top of the first row of piezometer holes (Barnard and McBain 1994; Dahm and Valett 1998). Positive VHG values indicate upwelling occurrence and negative values indicate areas of down-welling (Freeze and Cherry 1979). Kolor Kut water finding paste (Kolor Kut Products Company LTD, Houston Texas) was used in 2004 to measure water levels in the mini-piezometers. The paste changes color from a light brown to bright red when exposed to water. Measurements would be taken by coating approximately two inches of the bottom of a very small diameter steel rod with the paste. A pair of vice-grips was used to hold the steel rod. They would be clamped on leaving approximating the length needed to submerge the rod end by an inch. This rod would be lowered along side, or into, the mini-piezometer until the coated end made good contact with the water surface and the vice-grips jaw tips were in contact with the top of the mini-piezometer. A small stilling well was used when water current made readings difficult.

Water velocity and depth measurements were also recorded. Water velocity was measured using a digital current meter just prior to introducing adults, immediately after all adults in a channel have perished and then monthly until fry emigration had ceased. Velocities were measured just upstream of the two weirs and the south channel's confluence, three readings were taken at each location to calculate a mean. Water depth was measured by placing staff gauges on the upstream side of each weir. Staff gauge levels were recorded every other day during the fall and early winter, then daily once fry trapping began through the end of the season. Changes in staff gauge readings due to activities such as installing and removing grates in the weirs and installing fry traps were recorded so readings could be normalized over the season.

Results

Gravel samples were taken from all three channels, 60 samples, in October of 2003 and from only the middle and north channels, 40 samples, in May of 2004. Because adults have not utilized the south channel, this channel was not sampled in 2004. Samples were dried in preparation for analysis in August 2004. However, the gravel sieve shaker had a mechanical failure while processing the first sample. Steps were taken to procure a replacement sieve shaker but it was not available in time to processes the samples before this report was finalized.

Both sub-surface and mid-water temperature data loggers were in place by November 4, 2003. Temperature loggers were recovered on April 29, 2004. Two of the sub-surface data loggers, middle channel #3 and north channel #3, could not be recovered due to locating cable breakage. Data from the mid-water data logger at the bottom of the south channel was not downloadable due to data logger damage. Daily average water temperatures were calculated for each data logger and these results are reported in **Appendix B.** Table 1. Additional values of sub-surface and mid-water temperature values are available from the bi-monthly sampling at the mini-piezometers (Table 11). Piezometers were assigned numbers, increasing sequentially, from the top of the channel to confluence for the south channel and to the weirs for the other two channels. Values reported as top and bottom in Table 11 are those recorded outside the first and last piezometer in each channel. Mean DO values from bi-monthly sampling at the piezometers are recorded in Table 12.

Measurements to calculate VHG were recorded on January 13 and April 26, 2004. VHG data collection scheduled at the end of December was delayed until almost mid-January due to a sever winter snowstorm preventing access to the site. In addition to these formal measurements, a visual check for VHG was made and recorded at each mini-piezometer when DO and temperature values were made on several sampling days. These results, both measured and visual, are reported in Table 13 (a comment of "yes" indicates up-welling, "no" indicates no difference, or "down" indicates down-welling) for the dates when only visual checks were made.

Water velocities were measured using a digital current meter once adults were placed in the channels, and then monthly through April. Measurements were taken in front of each weir and, on several occasions, at the confluence of the south channel with the middle channel (Table 14.) During the months when grates or fry traps were in place at the weirs, these were thoroughly cleaned and any head created was allowed to recede before measurements were recorded.

Staff gauges were placed on the upstream side of both weirs on November 21, 2002. No attempt was made to set the two gauges to read equal heights in relation to each other. Survey measurements were taken on January 9, 2003, to determine the difference in height of the staff gauges. Corresponding heights on the two gauges differed by an estimated 0.88 feet, with the north weir being lower. This difference is due to elevation differences in the two channels. Staff gauges were placed so that measurements recorded allowed comparison of water depth at the weir slots. These gauges are not removed between seasons allowing for direct comparisons between years. Staff gauge heights were recorded on an every-other-day basis when adult chum salmon were present, sporadically during the incubation period, and then daily once fry trapping began (Table 15). During the months when grates or fry traps were in place at the weirs, these were thoroughly cleaned and any head created allowed to recede before measurements were recorded. The values reported in Table 15 were corrected for the differences made in water heights due to grates, fry traps and sand bag placement for fry trapping, and represent what these values would theoretically be without these obstructions.

Table 11. Mean water temperature values from mini-piezometer sampling, 2003-04.

South channel		Mini-piezometer #								
Date	Top	1	2	3	4	5	6	7	8	Bottom
12/02/2003	9.9	9.80	9.40	9.40	9.30	9.40	9.40	9.30	9.30	9.4
12/17/2003	9.6	9.40	9.20	9.20	9.00	9.10	9.00	8.90	9.00	9.0
01/13/2004	8.3	7.20	Dry	8.00	8.10	7.70	8.10	8.20	8.10	8.4
02/02/2004	7.2	7.30	6.90	7.40	7.80	7.40	7.50	7.40	7.30	7.6
02/18/2004	8.4	8.40	8.20	8.20	8.30	8.30	8.40	8.40	8.30	8.2
03/01/2004	8.5	8.60	8.60	8.50	8.60	8.70	8.60	8.80	8.80	8.7
03/15/2004	8.8	8.80	8.50	8.70	8.70	8.70	8.70	8.80	8.80	8.6
03/29/2004	8.5	9.20	9.10	9.40	9.00	8.90	8.90	8.90	9.00	8.7
04/12/2004	8.9	8.70	9.20	8.90	9.20	9.40	9.30	9.10	9.20	9.3
04/26/2004	10.5	9.20	Dry	9.30	9.90	9.80	9.50	9.90	9.80	12.5

Middle channel		Mini-piezometer #				
Date	Top	1	2	3	4	5	Bottom
12/02/2003	9.1	9.10	9.10	9.10	9.10	9.30	9.3
12/17/2003	8.8	8.60	8.80	8.70	8.70	8.90	8.8
01/13/2004	8.3	8.00	8.10	8.20	8.30	8.30	8.4
02/02/2004	7.5	7.40	7.60	7.60	7.50	7.60	7.7
02/18/2004	8.4	8.40	8.50	8.50	8.70	8.40	8.4
03/01/2004	8.7	9.00	8.90	8.90	9.20	9.10	8.9
03/15/2004	8.7	9.20	9.00	9.00	9.20	9.00	8.7
03/29/2004	8.7	9.00	9.00	9.10	9.30	9.10	8.8
04/12/2004	8.8	9.30	9.20	9.30	9.40	9.50	9.3
04/26/2004	9.3	9.30	9.20	9.40	9.30	9.50	10.4

North channel		Mini-piezometer #				
Date	Top	1	2	3	4	Bottom
12/02/2003	8.7	8.60	8.10	8.50	8.40	8.7
12/17/2003	8.0	8.10	7.50	7.70	7.70	7.3
01/13/2004	8.0	8.00	7.50	7.70	7.60	7.6
02/02/2004	6.2	6.80	6.40	6.70	6.40	6.4
02/18/2004	7.8	8.10	7.60	8.00	7.90	7.7
03/01/2004	7.9	8.40	8.10	9.10	9.10	8.7
03/15/2004	8.1	9.00	8.60	8.50	8.50	8.2
03/29/2004	8.3	9.00	9.10	9.10	8.60	8.8
04/12/2004	8.6	8.90	9.00	9.10	9.10	8.8
04/26/2004	8.8	8.90	9.40	9.50	9.60	10.2

Table 12. Mean DO values from mini-piezometer sampling, 2003-04

South channel					Mini-piezometer #				
Date	Top	1	2	3	4	5	6	7	8	Bottom
12/02/2003	7.73	8.23	7.97	9.83	9.90	9.13	8.97	10.17	11.57	9.90
12/17/2003	8.77	8.07	9.47	10.30	9.90	9.47	8.37	10.23	5.40	9.47
01/13/2004	11.13	10.07	Dry	12.27	11.30	11.80	10.53	13.40	5.43	11.53
02/02/2004	12.30	11.93	12.03	11.13	12.03	12.07	12.13	11.33	12.03	12.00
02/18/2004	12.03	11.43	11.70	12.00	11.63	11.77	12.10	11.57	11.63	11.37
03/01/2004	12.73	11.23	11.63	11.43	14.73	11.77	11.57	10.23	10.63	10.37
03/15/2004	12.93	12.70	46.80	12.60	16.13	7.00	10.13	13.60	9.33	12.23
03/29/2004	16.30	16.77	14.50	11.23	12.40	6.40	7.20	9.50	6.30	13.13
04/12/2004	13.13	7.77	7.77	11.30	11.03	10.17	11.10	13.20	7.23	12.77
04/26/2004	10.13	3.10	Dry	6.10	5.00	6.80	6.00	8.10	1.00	12.20

Middle channel			Mini-piezometer #				
Date	Top	1	2	3	4	5	Bottom
12/02/2003	9.77	9.83	9.93	12.73	10.60	6.70	9.93
12/17/2003	9.13	7.33	4.70	7.83	9.17	7.80	9.83
01/13/2004	11.43	9.83	7.03	7.27	7.93	10.50	12.90
02/02/2004	14.30	12.40	8.77	10.23	11.50	12.10	12.37
02/18/2004	13.07	11.87	12.67	10.37	10.63	11.47	11.20
03/01/2004	11.10	13.53	12.93	14.47	14.10	11.93	11.40
03/15/2004	11.90	9.70	3.00	3.43	5.80	7.70	13.03
03/29/2004	11.27	10.03	3.40	7.40	5.40	7.60	10.73
04/12/2004	11.17	7.80	2.20	11.73	6.37	10.03	11.03
04/26/2004	10.90	6.10	2.90	10.47	4.77	8.40	12.07

North channel			Mini-piezometer #			
Date	Top	1	2	3	4	Bottom
12/02/2003	9.70	2.73	10.17	13.67	11.70	9.93
12/17/2003	9.20	2.30	8.90	14.03	11.10	10.10
01/13/2004	10.90	2.37	6.50	14.43	12.47	12.90
02/02/2004	14.13	8.67	9.67	11.63	12.63	12.10
02/18/2004	15.07	12.67	10.93	12.40	12.67	13.27
03/01/2004	12.07	11.03	12.53	11.90	13.17	13.10
03/15/2004	11.80	3.00	10.77	13.33	13.50	13.90
03/29/2004	14.33	3.50	9.77	11.10	14.37	14.03
04/12/2004	10.43	2.40	9.23	10.70	11.23	9.87
04/26/2004	10.47	0.40	5.90	12.70	8.50	11.40

Table 13. Results of VHG sampling, both measured and visual, 2003-04

South channel	Mini-piezometer #							
Date	1	2	3	4	5	6	7	8
11/26/2003	No	No	No	No	No	Yes	No	Ys
12/17/2003	No	No	No	No	No	Yes	Yes	no
01/13/2004	0.01	Dry	0.02	-0.11	-0.81	-0.01	0.05	0.03
02/02/2004	No	WTF	WTF	WTF	No	Yes	No	No
02/18/2004	No	WTF	WTF	WTF	WTF	Yes	Yes	Yes
03/01/2004	Yes	WTF	WTF	WTF	No	Yes	WTF	Yes
03/15/2004	No	WTF	WTF	WTF	Down	Yes	WTF	Yes
03/29/2004	Yes	WTF	WTF	WTF	No	Yes	WTF	Yes
04/12/2004	No	Down	Yes	No	Down	No	Yes	No
04/26/2004	0.01	Dy	0.02	-0.44	-0.90	0.00	0.04	0.03

WTF= water to fast to estimate VHG visually

Middle channel	Mini-piezometer #				
Date	1	2	3	4	5
11/26/2003	Yes	No	Yes	Yes	Yes
12/17/2003	Yes	Yes	Yes	No	No
01/13/2004	0.09	0.02	0.07	-0.02	0.01
02/02/2004	Yes	Yes	Yes	Yes	Yes
02/18/2004	Yes	Yes	Yes	Yes	No
03/01/2004	Yes	Yes	Yes	Yes	No
03/15/2004	No	No	Yes	No	No
03/29/2004	Yes	Yes	Yes	No	No
04/12/2004	Yes	No	Yes	No	No
04/26/2004	0.04	0.06	0.04	0.17	-0.06

North channel	Mini-piezometer #			
Date	1	2	3	4
11/26/2003	Yes	Yes	No	No
12/17/2003	Yes	Yes	Yes	Yes
01/13/2004	0.01	0.01	0.14	0.06
02/02/2004	Yes	Yes	No	Yes
02/18/2004	Yes	Yes	Yes	No
03/01/2004	Yes	Yes	No	No
03/15/2004	Yes	Yes	No	No
03/29/2004	Yes	Yes	Yes	No
04/12/2004	Yes	Yes	No	No
04/26/2004	-0.08	0.09	0.00	0.03

Table 14. Water velocity measurements (fps) at the two weirs in the Duncan Spawning Channels.

Date	South weir	North weir	South channel confluence
11/26/2003	0.104	0.428	0.234
01/13/2004	Not measurable	0.560	0.099
02/02/2004	0.258	0.558	1.313
03/01/2004	0.261	0.179	1.077
03/29/2004	0.069	0.128	0.688
04/26/2004	Not measurable	0.207	0.183

Table 15. Staff gauge heights recorded at the two weirs, 2003-04.

Date	South	North	Date	South	North	Date	South	North	Date	South	North
11/15/2003	0.64	0.62	12/21/2003	0.80	0.69	03/15/2004	0.81	0.57	04/17/2004	NA	0.41
11/16/2003	0.71	0.78	12/22/2003	0.80	0.67	03/16/2004	0.78	0.59	04/18/2004	NA	0.40
11/17/2003	0.82	0.72	12/23/2003	0.79	0.77	03/17/2004	0.78	0.58	04/19/2004	NA	0.41
11/18/2003	0.88	1.00	12/24/2003	0.77	0.71	03/18/2004	0.78	0.57	04/20/2004	NA	0.39
11/19/2003	1.00	0.80	12/26/2003	0.75	0.61	03/19/2004	0.78	0.57	04/21/2004	NA	0.41
11/20/2003	0.86	0.67	12/27/2003	0.74	0.60	03/20/2004	0.75	0.56	04/22/2004	NA	0.41
11/22/2003	0.83	0.73	12/28/2003	0.78	0.62	03/21/2004	0.83	0.57	04/23/2004	NA	0.41
11/24/2003	0.83	0.80	12/30/2003	0.76	0.60	03/22/2004	0.78	0.57	04/24/2004	NA	0.41
11/25/2003	0.92	1.10	01/02/2004	0.75	0.61	03/23/2004	0.78	0.56	04/25/2004	NA	0.40
11/26/2003	0.82	0.77	01/10/2004	0.73	0.60	03/24/2004	0.78	0.56	04/26/2004	NA	0.39
11/28/2003	0.81	0.63	01/13/2004	0.72	0.60	03/25/2004	0.75	0.52	04/27/2004	NA	0.38
11/29/2003	0.85	0.89	02/02/2004	0.97	0.84	03/26/2004	0.75	0.56	04/28/2004	NA	0.38
11/30/2003	0.90	0.79	02/18/2004	0.94	0.78	03/27/2004	0.78	0.48			
12/01/2003	0.96	0.94	02/23/2004	0.91	0.79	03/28/2004	0.84	0.53			
12/02/2003	0.82	0.69	02/25/2004	0.90	0.79	03/29/2004	0.82	0.50			
12/04/2003	0.77	0.65	02/26/2004	0.88	0.63	03/30/2004	0.76	0.48			
12/05/2003	0.80	0.68	02/27/2004	0.88	0.63	03/31/2004	0.75	0.48			
12/06/2003	0.86	0.81	02/28/2004	0.88	0.67	04/01/2004	0.73	0.47			
12/07/2003	0.93	0.74	02/29/2004	0.93	0.62	04/02/2004	0.73	0.47			
12/08/2003	0.86	0.66	03/01/2004	0.88	0.59	04/03/2004	0.72	0.45			
12/09/2003	0.95	0.95	03/02/2004	0.83	0.61	04/04/2004	0.71	0.46			
12/10/2003	0.94	0.83	03/03/2004	0.83	0.62	04/05/2004	0.73	0.45			
12/11/2003	0.87	0.64	03/04/2004	0.87	0.62	04/06/2004	0.67	0.43			
12/12/2003	0.94	0.84	03/05/2004	0.86	0.60	04/07/2004	0.64	0.43			
12/13/2003	0.80	0.92	03/06/2004	0.86	0.61	04/08/2004	0.65	0.43			
12/14/2003	1.04	0.70	03/07/2004	0.84	0.62	04/09/2004	0.64	0.42			
12/15/2003	0.94	0.76	03/08/2004	0.84	0.62	04/10/2004	0.64	0.41			
12/16/2003	0.96	0.80	03/09/2004	0.82	0.60	04/11/2004	0.66	0.42			
12/17/2003	0.97	0.76	03/10/2004	0.82	0.60	04/12/2004	NA	0.42			
12/18/2003	0.83	0.61	03/11/2004	0.81	0.60	04/13/2004	NA	0.46			
12/19/2003	0.85	0.64	03/12/2004	0.79	0.58	04/14/2004	NA	0.44			
12/20/2003	0.93	0.66	03/13/2004	0.79	0.60	04/15/2004	NA	0.43			
11/15/2003	0.64	0.62	03/14/2004	0.81	0.56	04/16/2004	NA	0.42			

Because of decreased discharge, sandbags were placed directly behind the fence weir panels at the south weir fry trap and screen cleaning was halted on 4/12/04. Because of this, no values for that gauge are reported here after that date.

Discussion

Analysis of gravel samples will occur after this report is finalized, and will be reported in the 2005 annual report. However, the 2004 egg-to-fry survival rates in both channels indicate that channel gravel incubation conditions remained favorable

Temperatures recorded from inside the mini-piezometers, and mid-water values measured at the top and bottom of each channel, ranged from 7.2 to 12.5 ^{o}C. Daily average temperatures recorded by data loggers placed in the spawning gravel of the middle and north channels (the two channels used by adults) ranged from 5.8 to 9.3 ^{o}C, well above the 2.2 ^{o}C minimum that can negatively impact spawning and incubation (Schroder 1973; Koski 1975). DO levels recorded in the mini-piezometers of the middle and north channels in or near areas where spawning took place varied over the season but remained at or above acceptable levels. The dramatic decrease in DO levels measured in mini-piezometer #2 of the middle channel at the end of the season was not a concern as no spawning took place in this area. Results of VHG measurements in 2004 followed a pattern similar to that seen in 2003. As was the case in 2003, water velocity measurements taken at the two collection weirs were consistently lower than recommended in the Schroder (2000). However, water velocities recorded in 2004 were greater than those recorded in 2003. This increase may be due to the middle and north channels being extended prior to the 2003 spawning season to repair damage done to the top ends of both channels during the winter of 2003.

Continued monitoring of the hyporheic zone including temperature, gravel composition, hydraulic gradients, and DO levels will continue to ensure that the incubation environment in the Duncan Creek channels is suitable for this ESA-listed species. Reestablishment of a Duncan Creek spawning population will help reduce risks to LCR chum salmon.

Part IV: Natural Spawning

Introduction

Recolonization by adults straying from the LG population and the capture and release of LG population adults into the channels were the two primary means of initiating natural spawning in the Duncan Creek spawning channels. Adult chum salmon captured in Duncan Creek could either be placed above the weirs in the spawning channels to reproduce naturally, or transported to the Washougal Hatchery for use in a hatchery supplementation program. The reproductive success of adults placed in the spawning channels is estimated by evaluating egg-to-fry survival rates. To evaluate egg-to-fry survival rates in naturally spawning fish, two estimates of egg deposition are needed: Potential Egg Deposition (PED) and Actual Egg Deposition (AED), and the total number of fry captured at each channel's weir. As detailed in the Duncan M&E, egg-to-fry survival rates should exceed 40% if the channels were constructed and being maintained correctly, and female densities remain at less than one female per three square meters.

PED relies on relationships between phenotypic traits such as length or body weight, to estimate the fecundity of an individual female. Body size/fecundity relationships have been developed by researchers for several salmonid species (see Pritchard 1937; Rounsefell 1957; Allen 1958; Donaldson and Menasveta 1961; Gray 1965; Smolei 1966; Kato 1978; Gall and Gross 1978; Schroder 1981). These researchers showed that 10 to 70% of the variation in fecundity could be explained with female size (length or weight). Schroder (unpublished data) was able to explain 95% of the variation in fecundity of artificially spawned Grays River chum salmon in 1998 and 1999 by using multiple regression analyses of log body weight, egg weight and transformed reproductive effort (total egg mass weight/total body weight). While egg weight and length data can be collected from live fish, reproductive effort requires that the fish be spawned artificially. Removal of the reproductive effort value reduced the amount of variance that could be explained. Replacing reproductive effort with a K value (weight/length cubed) in the regression models resulted in formulas that could explain 67 to 94% of the variation associated with fecundity. Schroder (2000) recommends artificially spawning 30-50 females to develop regression formulas that can be used to predict fecundity. Multiple years of data must be collected on artificially-crossed females of the LG population to develop these fecundity relationships and to measure yearly variation. AED equals PED minus any potentially viable (not deformed or still firmly attached to the ovarian membrane) eggs retained by the female at death. This is simply measured by sampling the females soon after death (< 24 hours) and counting potentially viable eggs.

Success of adults spawning in the channels can also be measured by estimating the number of returning adults from natural matings that occurred in the Duncan Creek spawning channels, the fry-to-adult survival rate called for in the LCR chum salmon recovery strategy. This requires that all fry be trapped when migrating out of the spawning channels and marked for identification as adults. Lastly, adult chum salmon returning to spawn from Bonneville Dam downstream to the I-205 bridge would need to be sampled for Duncan Creek project marks and an estimation of adult abundance in the different spawning locations made. Unlike juveniles trapped in 2002 and 2003, which were not marked with strontium (Sr) due to lack of required permits to apply and dispose of the strontium, fry trapped in 2004 were marked with strontium. Strontium marking was carried out under an Investigational New Animal Drug (INAD), permit # 010536 D-0005, issued by the Federal Food and Drug Administration Center for Veterinary Medicine.

Methods

Adults placed into the channels were collected by WDFW and PSMFC from known local chum spawning areas using the same methods described for hatchery brood stock collection. A normalized collection curve was developed using historical run timing for tributary spawners (Figure 12). Adults selected to be placed above the weirs were placed into a fish tube as described in the hatchery section earlier in this report. If the fish needed to be transported, a 400-gallon truck-mounted tank was used. Numbered Floy anchor-dart tags (Floy Tag & Manufacturing, Inc., Seattle WA.), one on each side of the dorsal, were applied on all adults moved into the spawning channels above the weirs. Weekly spawning ground surveys of Duncan Creek and the channels below the weirs were conducted by PSMFC personnel. All adult chum observed, dead or alive, were enumerated and biological samples were collected on all post-spawn mortalities. Biological sampling included: taking tissue samples for genetic analysis, scales for aging, lengths (fork (mm) and mid-eye-to-hypural plate (mm)) and the number eggs retained in females. The sex, location and tag number(s), if present, were also recorded. WDFW and PSMFC conducted additional daily surveys above the weirs to collect these data on post-spawn mortalities of adults.

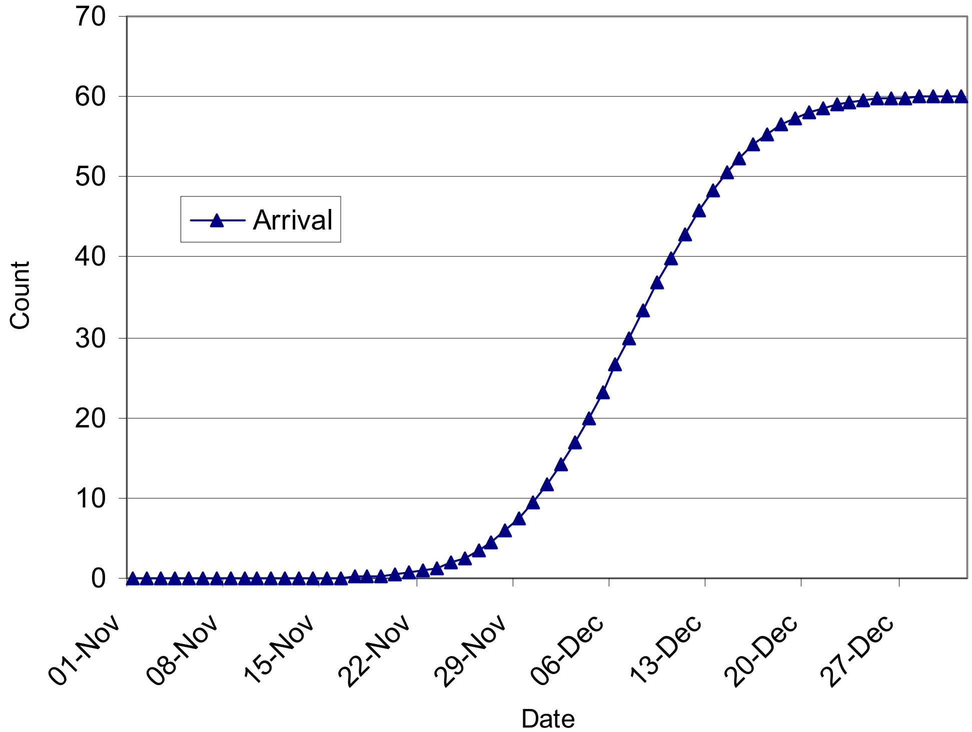


Figure 12. Normalized timing of Hamilton and Hardy Creek chum salmon from historical data, used for Duncan Spawning Channel brood stock collection (WDFW, unpublished).

Estimation of the PED for each female placed in the spawning channels would ideally be calculated by multiple regression formulas using body weight, egg size and K. If egg size was unknown for an individual female because all of her eggs were deposited, formulas using body weight and K or just body weight, whichever explains the greatest amount of variation, would be used. Regardless of the formula, 95% confidence intervals were calculated and three values (expected, upper and lower 95% CI) were developed for each female. These individual values were summed creating an expected, upper and lower 95% CI of PED for each channel.

Data to calculate values of AED for individual females were collected during daily surveys above the weirs. Egg size would be measured by randomly collecting up to ten eggs from any female found with viable retained eggs. These eggs would be placed in water, refrigerated for 24 hours, blotted dry and individually weighed to the nearest milligram. Egg size has been shown to vary little within a female. Modal coefficient of variation for Grays River females equaled 2.5% (Steve Schroder, pers. comm.). A sample of one or two eggs can be used to determine egg size (Schroder 2000). After sampling, the carcass was removed from the channel and placed into the riparian zone of Duncan Creek to constrain pathogens and maintain DO levels in the channels.

Enumeration of out-migrating fry was done with downstream migrant traps at two weirs, put into place during channel construction. When operated properly, the weirs should be 100% efficient in capturing juveniles, and the outmigration will be a count rather than an estimate. One weir is below two channels, the south and middle, the other is below the north channel (Figure 10). Fence-panel weir fry traps were used to capture the migrating fry in 2004 (Blankenship and Tible 1980) . These were the same traps used in 2003, with some minor modifications. An additional piece of fine mesh vexar was added to the bottom edge of every panel (Figure 13). When installing the fry traps, trenches were dug in the gravel to set the fence-panel weirs in. Then, with the added strip of vexar lying along the bottom, the trench was filled with gravel. This effectively formed a barrier preventing fry from swimming through the gravel or under the bottom of the fence-panels. In 2003, sand bags were used to accomplish this and some fry were impinged between the sand bags and the fence-panel weirs (Figure 14). Not having the sand bags at the base of the weirs also increased the available de-watering area when compared to 2003.

Traps were checked daily by either WDFW or PSMFC personnel. All trapped fish were enumerated, marked and released each day; mortalities and their location (on fence panels or in live box) were recorded. Strontium marking was accomplished via a four-hour immersion in a marking bath with a concentration of 1000 ppm strontium chloride hexahydrate. Because of concerns over on-site disposal and storage of marking water, a re-circulating marking bath was designed (Figure 15). The marking bath system was constructed using two totes, one acting as a sump and the other for holding the fry. Water movement was accomplished via a Dolphin 2100 Aqua Sea Amp Master aquarium hobby pump. The effluent from this pump was divided; about 25% went to the fry holding tote with the remaining water directed to a packed column. A packed column was incorporated into the system to provide de-gassing, oxygenation and to provide surface area for biological filtration to take place. Water pumped to the holding tote first passed through an Aqualogic 1/3 hp Delta Star chiller and an Aqua UV 25 watt UV sterilizer that were plumbed in-line. Heating, when needed, was provided by two 350 watt Pro-Heat II Titanium IC Heaters. Heating and cooling were controlled by a Medusa Dual Stag (3-Digit) Precision temperature controller. A 1/6-inch mesh net bag, made by Research Nets Inc. to the inside dimensions of a tote and seen hanging over the lip of the holding tote in Figure 15, was used to make fry removal easier. To accomplish dusk/nighttime releases, fry were removed from the live boxes and placed into the marking bath so that the end of the four-hour marking period coincided with dusk/nighttime and the fry could be immediately released. Direct mortality associated with strontium marking or sampling was evaluated. Every Monday, up to 200 fry from that day's collection, divided into treatment and control groups, were held for 48 hours to asses delayed mortality. Every Wednesday, five fry from the treatment group were taken Washougal Hatchery to be grown out and then sacrificed for voucher samples.

Figure 13. Fine mesh vexar extensions added to fry trap fence-panels in 2004.

Figure 14. Fence panel-weir fry trap operated at the south weir in 2003 showing sand bags.

Figure 15. The re-circulating strontium marking bath, 2004.

Up to thirty randomly chosen fry from each channel were weighed (0.01 g) and measured (fork length) every Monday, Wednesday and Friday. These values were used to calculate K_D values (Bams 1970) for individual fish.

Results

A total of 16 live chum salmon were observed during three spawning ground surveys conducted below the weirs of the channels and in Duncan Creek between November 29 and December 13, 2003. Because the adult trap at the dam was only operated for four days during the 2003 adult migration period, the exact number of adult chum salmon and other salmonids that volitionally entered Duncan Creek is unknown. Rawding and Hillson (2004, in prep) reported that the LG chum salmon population (Ives Island, Multnomah and St. Cloud groups, excluding tributary spawners) for the fall of 2003 was 1,787, yielding an observed stray rate (16/1,787) of 0.90 percent. This extremely low rate is not surprising given the low water conditions present in the Columbia River and Duncan Creek during the fall of 2003.

Fifty-four adults (27 females and 27 males) were released above the weirs into the Duncan Creek spawning channels. One female collected for the spawning channels from the Multnomah area on December 12 died, cause of mortality unknown, in a live carrying tube during transport while still in the boat. Tables 16 and 17 detail the locations were adult chum salmon placed into the spawning channels were collected. The number of adults to be placed in each channel was determined prior to the adult collection season in 2003. However, as was the case for hatchery brood stock, low adult abundance in the Ives/Pierce Island area hampered adult collection activities.

Table 16. Adult seining data, 2003.

Date	Location	Chum	Chinook	Coho	Steelhead	
					Marked	Un-Marked
11/05/03	Multnomah Area	0				
11/05/03	Woodward Creek	7				
11/06/03	Ives Area	28	22	10		
11/10/03	Ives Area	133	22	2		
11/10/03	Multnomah and St. Cloud	6				
11/12/03	Ives Area and Woodward Creek	73				
11/12/03	Multnomah and St. Cloud	17				
11/17/03	Ives Area and Woodward Creek	18	8	4		1
11/17/03	Multnomah Area	58		1		
11/19/03	Ives Area and Woodward Creek	Snow forced boat off the water				
11/19/03	Multnomah Area	78				
11/20/03	Ives Area and Woodward Creek	30	6			
11/25/03	Ives Area and Woodward Creek	58	7			
11/25/03	Multnomah Area	166				
12/01/03	Ives Area and Woodward Creek	49				
12/01/03	Multnomah Area	146				
12/03/03	Ives Area and Woodward Creek	28	1			
12/03/03	Multnomah and St. Cloud	193				
12/08/03	Ives Area and Woodward Creek	38	3			
12/08/03	Multnomah and St. Cloud	140				
12/10/03	Ives Area and Woodward Creek	48	8			
12/10/03	Multnomah and St. Cloud	119				
12/15/03	Ives Area and Woodward Creek	6	1			
12/15/03	Multnomah and St. Cloud	40				
12/17/03	Ives Area and Woodward Creek	7	1		1	
12/17/03	Multnomah and St. Cloud	4				
12/22/03	Ives Area and Woodward Creek	0				1
12/22/03	Multnomah and St. Cloud	Too windy to safely set nets				

Table 17. Date of capture and origin of adult chum salmon moved to Duncan Creek Channels, 2003.

			Duncan Creek Channels			
			Above south weir		Above north weir	
Date	Location	Number adult chum salmon seined	Male	Female	Male	Female
11/25/03	Multnomah Area	166	1	1	2	2
12/01/03	Multnomah Area	146		3		8
12/01/03	Ives Area	33	3		4	
12/01/03	Woodward Creek	16			4	
12/03/03	Ives Area	18			1	1
12/08/03	St. Cloud Area	46	2	2	5	5
12/08/03	Ives Area	35			1	1
12/10/03	Multnomah Area	68	1			
12/10/03	St Cloud Area	51	1	2		
12/15/03	St Cloud Area	18			2	2
	Total	597	8	8	19	19

All adults placed above the weirs in the channels were double Floy tagged, and their fork lengths recorded, prior to release. The middle channel received 16 adults (8 female, 8 males) and the north channel received 38 adults (19 female and 19 male). No adults escaped from above the weirs in 2003.

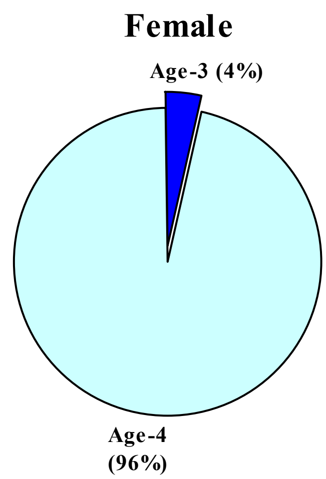
Biological data collected during spawning-ground surveys above the weirs is summarized in Table 18. Three scales were taken from each fish for age determination. Age-4 fish dominated the age structure of males placed above the weirs, 4% age-3, 88% age-4 and 8% age-5 (Figure 16). Age-4 fish also dominated the age structure of females placed above the weirs, 4% age-3 and 96% age-4 (Figure 16). A comparison of average fork and mid-eye-to-hypural lengths by age and sex can be found in Table 19. The one age-3 female had a recorded fork length of 633 mm, and age-4 females ranged from 613 mm to 785 mm, averaging 719 mm (Figure 17). The one age-3 male had a recorded fork length of 733 mm, age-4 males ranged from 670 mm to 882 mm, averaging 764 mm and age-5 males ranged from 740 mm to 822 mm, averaging 781 mm (Figure 18). The number of retained viable eggs for recovered females ranged from zero to 1,356 and averaged 104 (n=26).

Table 18. Biological data of adults placed in spawning channels, 2003-04.

Date released	Date sampled	Sex	Channel	Age	Fork length (cm)	Mid-eye-to-hypural (cm)	# of eggs retained	Comments
25-Nov	11-Dec	F	North	4	735	579	2	
25-Nov	11-Dec	F	North	4	704	559	78	
25-Nov	06-Dec	F	Middle	4	732	585	0	
25-Nov	12-Dec	M	North	4	786	582		
25-Nov	04-Dec	M	Middle	4	882	640		
25-Nov	07-Dec	M	North	4	775	580		
01-Dec	---	F	North	---	---	---	---	Not recovered after spawning
01-Dec	08-Dec	F	North	4	675	535	518	
01-Dec	11-Dec	F	North	4	758	602	276	
01-Dec	14-Dec	F	North	4	707	577	0	
01-Dec	10-Dec	F	North	4	747	587	90	
01-Dec	12-Dec	F	Middle	4	742	575	4	
01-Dec	12-Dec	F	Middle	4	785	618	0	
01-Dec	10-Dec	F	Middle	4	754	585	0	
01-Dec	10-Dec	F	Middle	4	745	580	0	
01-Dec	12-Dec	F	North	4	745	579	1	
01-Dec	11-Dec	F	North	4	708	566	182	
01-Dec	10-Dec	M	North	---	715	585		Unable to age this adult
01-Dec	18-Dec	M	North	4	755	557		
01-Dec	15-Dec	M	North	4	805	614		
01-Dec	19-Dec	M	North	4	872	640		
01-Dec	07-Dec	M	North	4	780	583		
01-Dec	12-Dec	M	North	4	766	572		
01-Dec	11-Dec	M	Middle	4	740	557		
01-Dec	07-Dec	M	Middle	4	705	527		
01-Dec	05-Dec	M	Middle	4	670	500		
01-Dec	09-Dec	M	North	5	740	615		
01-Dec	16-Dec	M	North	4	716	564		
03-Dec	19-Dec	F	North	4	712	558	1,356	
03-Dec	16-Dec	M	North	4	760	858		
08-Dec	18-Dec	F	North	4	613	485	6	
08-Dec	24-Dec	F	North	4	740	554	0	
08-Dec	21-Dec	F	Middle	3	633	502	0	
08-Dec	18-Dec	F	Middle	4	680	535	0	
08-Dec	18-Dec	F	North	4	740	585	129	
08-Dec	20-Dec	F	North	4	725	560	2	
08-Dec	19-Dec	F	North	4	680	540	0	
08-Dec	21-Dec	F	North	4	682	545	0	
08-Dec	15-Dec	M	Middle	4	808	597		
08-Dec	15-Dec	M	Middle	3	733	550		
08-Dec	17-Dec	M	North	4	700	515		
08-Dec	17-Dec	M	North	4	805	594		
08-Dec	17-Dec	M	North	4	790	593		
08-Dec	12-Dec	M	North	4	780	618		
08-Dec	16-Dec	M	North	4	762	568		
08-Dec	14-Dec	M	North	4	756	565		
11-Dec	17-Dec	F	Middle	4	753	585	0	Green at hatchery
11-Dec	22-Dec	F	Middle	4	715	556	10	Green at hatchery
11-Dec	18-Dec	M	Middle	4	695	520		From hatchery, paired up with green girl
11-Dec	16-Dec	M	Middle	4	763	562		From hatchery, paired up with green girl
15-Dec	02-Jan	F	North	4	737	575	0	
15-Dec	25-Dec	F	North	4	661	520	41	
15-Dec	24-Dec	M	North	5	822	599		
15-Dec	25-Dec	M	North	4	703	535		

Table 19. Average fork length (cm) and mid-eye-to-hypural lengths (cm) by sex and age of adults placed above spawning channel weirs, 2003.

Sex	Age	N=	Avg. fork length (cm)	Avg. mid-eye-to-hypural (cm)
Male	3	1	73.3	55.0
	4	23	76.4	58.4
	5	2	78.1	60.7
	Combined	26	76.4	58.5
Female	3	1	63.3	50.2
	4	25	71.9	56.5
	5	0	---	---
	Combined	26	71.6	56.3



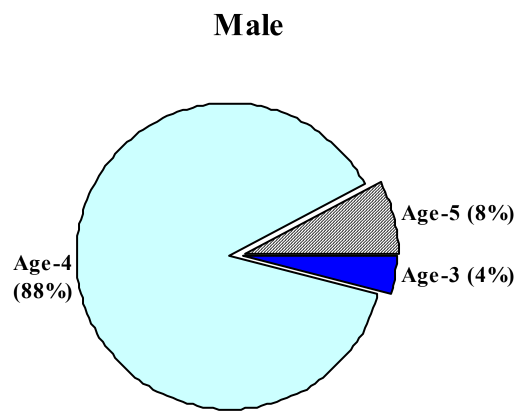


Figure 16. Age composition of adult chum salmon sampled in the Duncan Creek Spawning Channels, 2003.

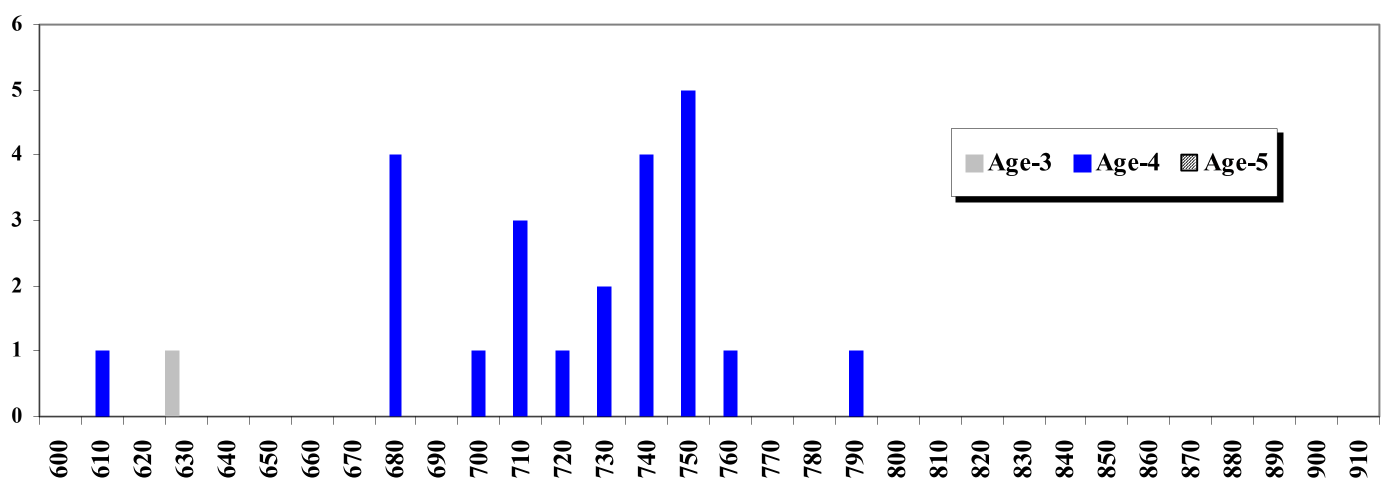


Figure 17. Fork lengths of female chum salmon placed in the Duncan Creek Spawning Channels, grouped by age and 10 mm increments, 2003.

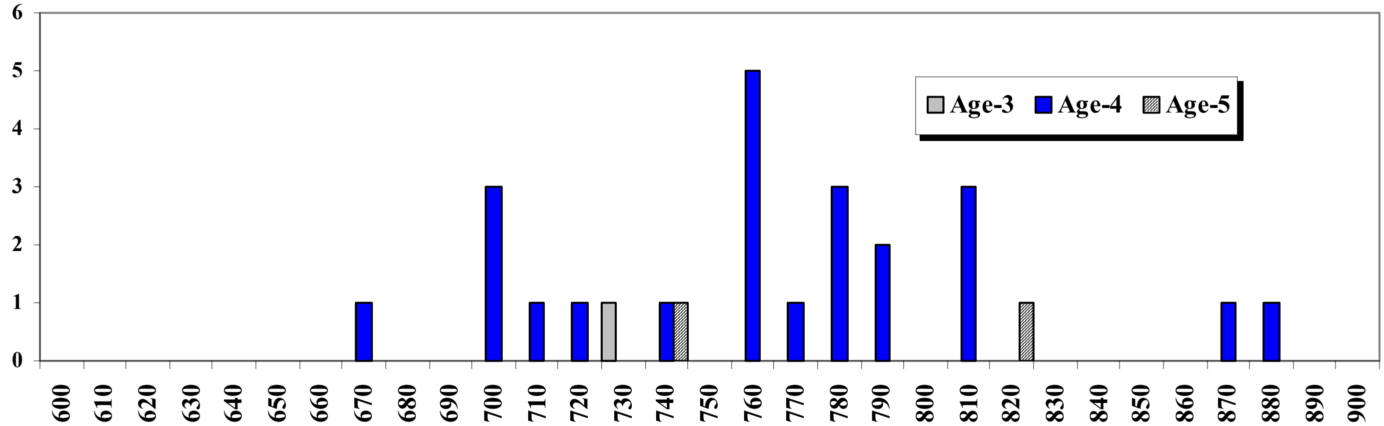


Figure 18. Fork lengths of male chum salmon placed in the Duncan Creek Spawning Channels, grouped by age and 10 mm increments, 2003.

Females spawned at Washougal Hatchery were used to create predictive regression formulas to estimate PED of females who spawned naturally in the channels. Individual reproductive values (total egg mass weight (g) / body weight (g)) were calculated for all females spawned at the hatchery. Females with reproductive values less than 16% have likely lost eggs or already spawned at least once in the river before capture (Steve Schroder, pers. comm.) and were not included in the regression analysis. Using this criterion, 19 sets of data were available for regression analysis in 2004, 59 and 17 sets were available in 2002 and 2001 respectively.

As was the case in 2001, the limited number of data sets available in 2004 resulted in fewer significant regressions available for PED estimation. However, when retained eggs were recovered and mean green egg weight was included in the analysis, the significance of the regressions were greatly increased. Multiple regression using Log10 MEtH length and mean green egg weight, all ages combined, was able to explain 76% (ANOVA $P \leq 0.0008$) of the variation in fecundity of females spawned at the hatchery. The best relationships were used to calculate age-3 and age-4 female PED values, age-3 Log10 fork lengths (R^2= 0.15, ANOVA $P \leq 0.24$) and age-4 Log10 MEtH length (R^2= 0.51, ANOVA $P \leq 0.07$) or all ages Log10 MEtH length and mean green egg size (R^2= 0.63, ANOVA $P \leq 0.14$) when possible respectively. Lastly, mean fecundity by age was calculated. Confidence intervals (95%) were calculated for all significant regressions and the mean fecundities by age to yield a PED value for each female that spawned in the channels. These values were summed to create the expected, upper and lower 95% CI for PED of each channel (Table 20).

Table 20. PED values (expected, lower and upper 95% CI) for the Duncan Creek Spawning Channels by method, 2004.

Channel	Expected	Lower 95% CI	Upper 95% CI
	Predictive fecundity regression formulas		
South	24,397	21,091	27,703
North	54,088	48,975	59,200
Total	78,485	70,066	86,903
	Using mean fecundity by age group		
South	24,349	21,713	26,985
North	58,339	54,115	62,562
Total	82,687	75,828	89,547

The number of retained eggs is known for all but one female that spawned above the weirs (Table 18). These values were converted to percent-retained eggs using the individual expected fecundity values derived from the predictive regression formula. The mean of these percentages (3.47%) was used as the retention rate for the one female that was not recovered. The mean value was used to give each sample value equal weight. This allowed AED values (expected, upper and lower 95% CI) to be calculated for each channel (Table 21).

Table 21. AED values (expected, lower and upper 95% CI) for the Duncan Creek Spawning Channels by method, 2004.

Channel	Expected	Lower 95% CI	Upper 95% CI
	Predictive fecundity regression formulas		
South	24,387	21,081	27,693
North	51,314	46,201	56,426
Total	75,701	69,612	81,789
	Using mean fecundity by age group		
South	24,339	26,975	21,703
North	55,565	59,788	51,341
Total	79,903	86,763	73,044

The number of fry captured in the Duncan Creek traps was used in conjunction with AED values to calculate expected, upper and lower 95% CI for egg-to-fry survival rates for the two channels. Intra-gravel temperatures, recorded bi-monthly from inside piezometers, were used to estimate daily temperature units (TUs) of the first eggs deposited in the channels, and thus estimate emergence. Limited historical data from the spawning channels suggest that 1550 to 1600 ^{o}F (860 to 890 ^{o}C) TUs are needed before any fry will be seen in the traps. To ensure that none were missed, fry trapping began at both weirs on February 27, six days before any fry would have reached 1500 ^{o}F TUs.

A total of 43,391 chum salmon fry (15,016 and 28,375 south and north weir traps respectively) were recovered from the two traps (Table 22). Daily trapping totals and cumulative percent passage at each weir are graphically displayed in Figures 19 and 20. Other salmonids trapped/seined included 30 coho (eight age 0+ and twenty-two age 1+, two of which were ad-clipped), two cutthroat trout, four unmarked trout/steelhead parr and two marked (ad-clipped) steelhead smolts (**Appendix C** Table 1). Daily trapping totals are reported in **Appendix C** Table 1. On April 27 and 28, the channels were seined and an additional 2,059 fry (523 above the south and 1,536 above the north) were recovered above the weirs. Very low spring rainfall that threatened to strand fry in the channels, so seining was initiated in late April to ensure juvenile chum salmon would emigrate before stranding could occur.

There was only one release of marked fish above the traps to estimate trapping efficiency. On April 15, 50 marked fry, marked by excising a portion of their upper caudal fin, were released after dark at the top of the middle channel. Only 29 of the 50 released were recovered during fry trapping activities, yielding a trap efficiency of 58%. However, five caudal clipped fry were recovered while seining on April 27. Removing these fry from the efficiency estimate results in a rate of 64%. Given the sturdiness and installation of the traps, it's unlikely that fry bypassed the traps. The 64% recovery rate for marks may be due to lack of mark ID or predation between release and recovery.

A total of 84 mortalities were recovered at the two traps, 32 and 52 from the south and north weir traps respectively, resulting in a trapping-related mortality rate of 0.2% (**Appendix C** Table 1). The trap at the south weir had daily mortality rates for chum salmon fry ranging from 0.0 to 8.3% with an overall season rate of 0.21%. The trap at the north weir had daily rates ranging from 0.0 to 6.3% with an overall season rate of 0.18%. The highest daily mortality rates for both traps occurred on days with collection totaled less than 16 fry. Four mortalities were recovered during seining at the end of the trapping season, bringing the total number of capture related mortalities to 88.

Table 22. Number of chum salmon fry trapped and seined from the Duncan Creek Spawning Channels, 2004.

	Chum salmon fry		
	Alive	Dead	Total
South weir trap	14,984	32	15,016
North weir trap	28,323	52	28,375
Trapping total	43,307	84	43,391
Seining	2,055	4	2,059
Combined	45,362	88	45,450

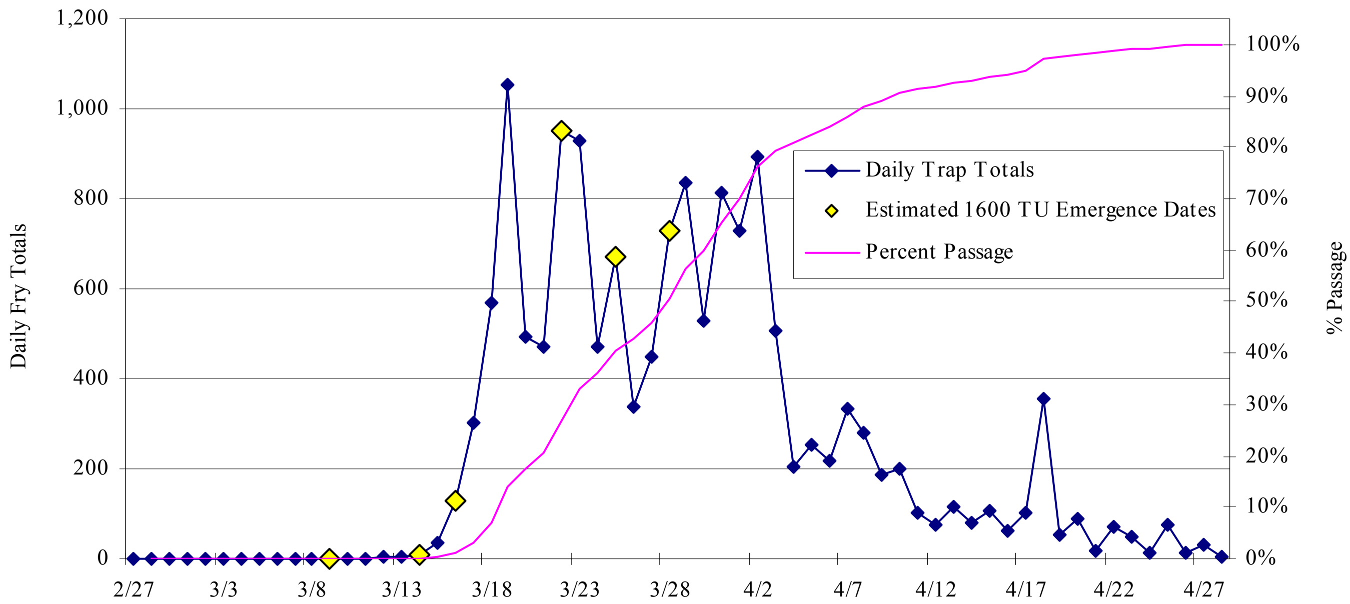


Figure 19. Daily collection totals of chum salmon fry at the south weir in the Duncan Creek Spawning Channels, 2004.

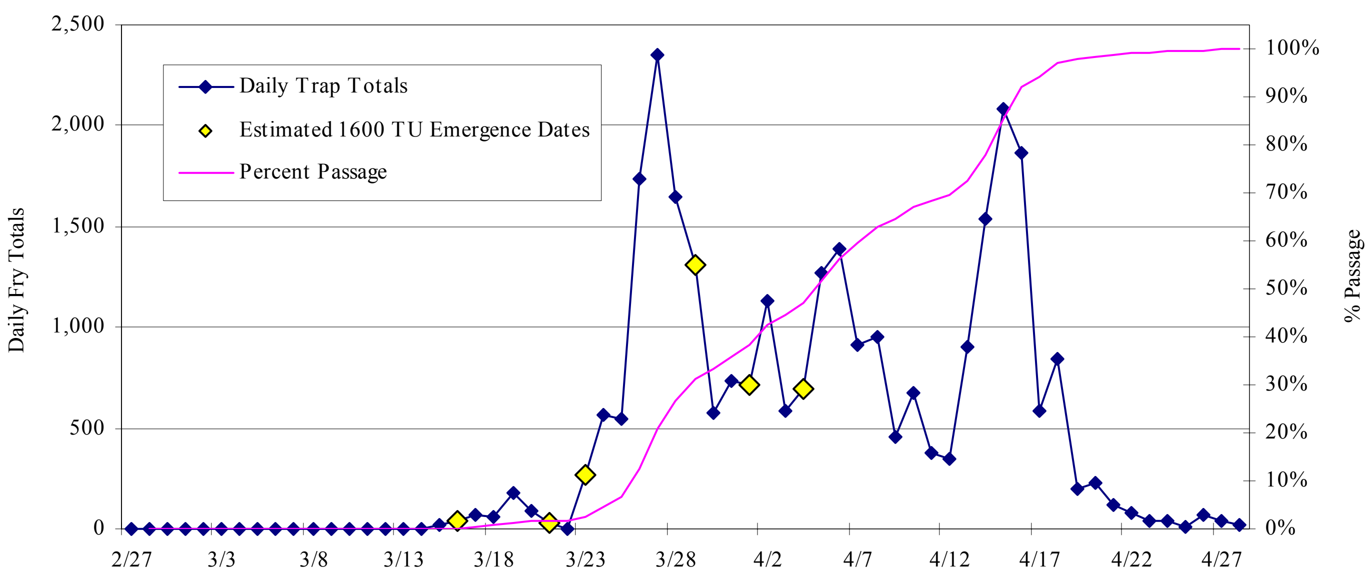


Figure 20. Daily collection totals of chum salmon fry at the north weir in the Duncan Creek Spawning Channels, 2004.

Individual weight and length data was collected on a maximum of 30 out-migrating fry from each trap at least three times a week, normally on Monday, Wednesday and Friday, throughout the season. Results of this sampling are presented in Table 23.

Table 23. Daily average weights, fork lengths and K_D values with 95% CI of chum salmon fry at the two traps, 2004.

South weir trap						North weir trap					
Date	Average weight (g)	Mean FL (mm)	n=	K_D	+/-	Date	Average weight (g)	Mean FL (mm)	n=	K_D	+/-
10-Mar	0.50	38.00	1	2.09	----	10-Mar			----		
12-Mar	0.46	39.40	5	1.96	0.09	12-Mar			----		
15-Mar	0.44	39.00	30	1.95	0.08	15-Mar	0.51	39.88	16	1.99	0.10
17-Mar	0.45	39.83	30	1.93	0.07	17-Mar	0.42	40.37	30	1.85	0.06
19-Mar	0.43	40.30	30	1.88	0.07	19-Mar	0.45	40.40	30	1.89	0.05
22-Mar	0.49	40.77	30	1.92	0.08	22-Mar	0.50	39.00	2	2.04	0.42
24-Mar	0.44	41.10	30	1.85	0.05	24-Mar	0.41	40.43	30	1.83	0.05
26-Mar	0.43	40.77	30	1.85	0.05	26-Mar	0.41	40.90	30	1.82	0.06
29-Mar	0.40	40.60	30	1.80	0.08	29-Mar	0.42	39.97	30	1.87	0.08
31-Mar	0.42	40.67	30	1.84	0.06	31-Mar	0.41	40.47	30	1.83	0.06
2-Apr	0.51	43.20	30	1.84	0.06	2-Apr	0.42	40.30	30	1.85	0.06
5-Apr	0.43	40.17	30	1.88	0.08	5-Apr	0.43	40.90	30	1.84	0.08
7-Apr	0.42	40.73	30	1.84	0.04	7-Apr	0.43	40.83	30	1.85	0.07
9-Apr	0.43	40.23	30	1.86	0.10	9-Apr	0.43	41.10	30	1.82	0.05
12-Apr	0.52	41.90	30	1.89	0.08	12-Apr	0.40	40.17	30	1.83	0.07
14-Apr	0.53	43.33	30	1.86	0.14	14-Apr	0.44	41.30	30	1.84	0.06
16-Apr	0.67	45.03	30	1.92	0.08	16-Apr	0.45	41.50	30	1.84	0.06
19-Apr	0.56	43.30	30	1.88	0.07	19-Apr	0.40	40.20	30	1.82	0.08
21-Apr	0.69	44.50	18	1.96	0.16	21-Apr	0.45	40.77	30	1.88	0.05
23-Apr	0.84	48.13	30	1.92	0.07	23-Apr	0.43	40.43	30	1.86	0.07
26-Apr	0.77	47.38	13	1.89	0.09	26-Apr	0.44	41.17	30	1.82	0.10
28-Apr	1.05	51.37	30	1.93	0.15	28-Apr	0.49	41.37	30	1.89	0.11

A total of 45,362 fry were placed into the strontium marking bath. Of these, eight died during the four-hour holding period resulting in a marking mortality rate of 0.018%. A total of 1,133 fry (566 and 567 in the control and test groups respectively) were used in the 48-delayed mortality evaluation. Only one mortality (from the test group) was recovered during the 48-hour holding period. A chi-squared test, with Yates continuity correction, was used to evaluate the differences in mortality between the two groups, and no significant difference was found at $\alpha = 0.05$ (chi-squared = 3.11328E-06, 1 df, p = 0.9986). This additional mortality results in a marking-related mortality rate of 0.02%. Five fry from each week's test group, 35 total for the season, were taken to Washougal Hatchery to be grown out and then sacrificed for voucher samples. Strontium-marked voucher fry were grown out so that additional bone would be present on the otolith outside of the strontium marked area. Each group of five voucher fry was reared separately. Removal of voucher fry and mortalities resulted in 45,318 strontium marked fry being released.

At the time of this report, four of the Sr marked voucher fry's otoliths had been examined for mark presence and clarity. Each otolith was mounted and sectioned according to normal procedures in the WDFW Otolith Lab. Polished hemi-sections were analyzed at the Center for Atmospheric and Oceanographic Science lab, Oregon State University, using Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS), where analysis transects from otolith core to edge provided a chemical profile for the entire life history of the fish until sampling. Operating conditions for the LA-

ICP-MS were similar to those used for salmonid studies in general, with a 30 um diameter beam firing at 8hZ and moving at 5 um/sec (Eric Volk, WDFW Otolith Lab, per. comm.). The results showed that the Sr marking treatments had a clear and measurable influence on strontium abundance in the juvenile otoliths Figure 21). While pre-treatment Sr/Ca values ranged narrowly between 1.2 and 1.5, treatment peaks were slightly less than three fold to slightly more than six fold greater. Assuming conditions that all freshwaters fish were exposed to during treatment and grow out were roughly similar with respect to Sr/Ca, this could only have been caused by the marking treatments and it is extremely unlikely that freshwater Sr/Ca values could be high enough to produce these peak values (Eric Volk, WDFW Otolith Lab, per. comm.).

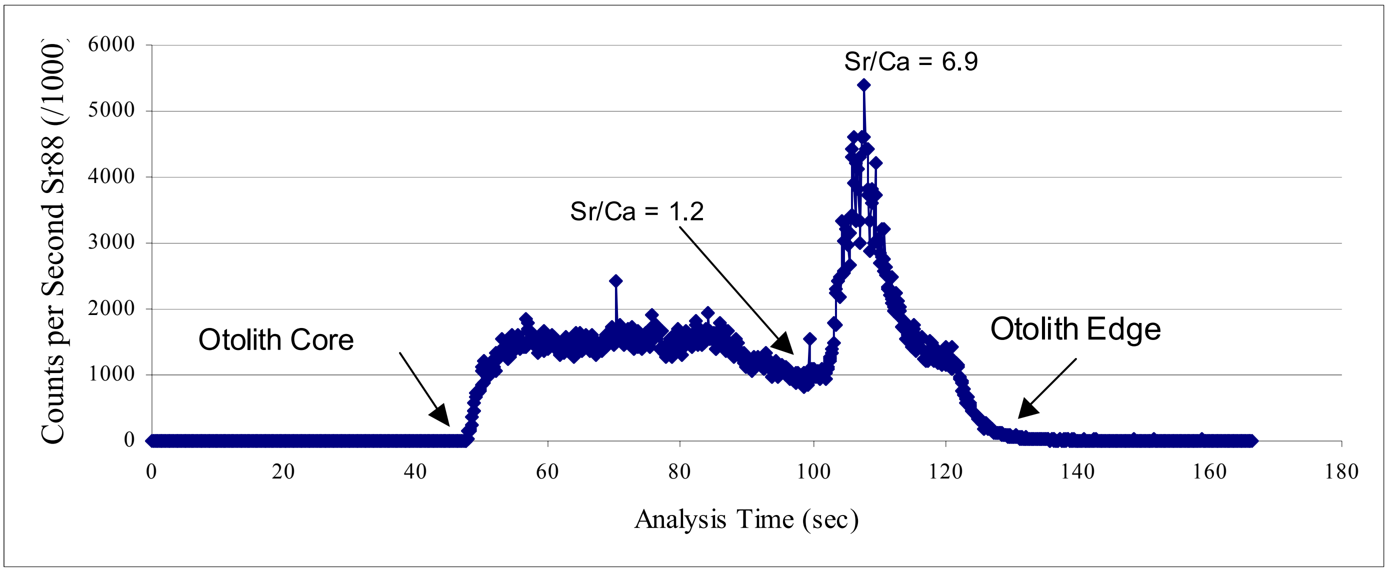


Figure 21. Graphical results of LA-ICP-MS analysis of a single Sr marked voucher fry's otolith showing the increase in Sr/Ca levels as a result of marking, 2004.

Table 24 details the egg-to-fry survival rates calculated using the AED estimates (expected, lower and upper 95% CI) from the predictive formulas, and mean fecundity rates. The number of fry used in these rates is the actual number trapped and seined with no expansion estimates done.

Table 24. Egg-to-fry survival rates (expected, lower and upper 95% CI) for the Duncan Creek Spawning Channels by method, 2004.

	Predictive fecundity regression formulas		
Channel	Expected	Lower 95% CI	Upper 95% CI
South	63.72%	56.11%	73.71%
North	58.29%	53.01%	64.74%
Total	60.04%	54.03%	67.55%
	Using mean fecundity by age group		
Channel	Expected	Lower 95% CI	Upper 95% CI
South	63.84%	57.61%	71.60%
North	53.83%	50.03%	58.26%
Total	56.88%	52.38%	62.22%

Discussion

The stray rate into Duncan Creek for 2003 was estimated to be near 0.9%, this compares to rates of 0.2% and near 1.0% for 2002 and 2001 respectively. At these low rates, it would take many generations for the Duncan Creek spawning channel to reach maximum capacity. Therefore, supplementation with evaluation should continue to ensure the rapid re-establishment of a spawning population in Duncan Creek.

Rawding and Hillson (2004 in prep) reported population estimates of 1,844 (+/- 1,715) in the Ives area, 1,024 (+/- 59) for the Multnomah area and 180 (+/- 25) at St. Cloud. Total numbers of adults handled for spawning-channel brood stock collection at these areas were 102, 380 and 115 at the Ives, Multnomah and St. Cloud areas respectively. Using these totals, the impacts (percent handled) for spawning-channels brood stock collection were estimated to be 5.5%, 37.1% and 63.9% at the Ives, Multnomah and St. Cloud areas respectively. Spawning-channel brood stock collection totals at these areas were 15, 18 and 21 adults at the Ives, Multnomah and St. Cloud areas respectively. Using these totals, the impacts (percent removed) for spawning-channel brood stock collection were estimated to be 0.8%, 1.8% and 11.7% at the Ives, Multnomah and St. Cloud areas respectively.

Chi^2 tests (Pearson's) were preformed to compare the age composition of adults released into the spawning channels versus adults spawning naturally in the mainstem Columbia River, adults used at the hatchery, adults spawning in Hamilton Creek and adults spawning at mainstem locations. Age composition for adults spawning in the mainstem came from sampling done in conjunction with brood stock collection and population estimation work. A summary of this analysis is presented in **Appendix A** Table 1. No significant differences ($P<0.05$) were found when comparing the age composition of adults released into the channels from a mainstem spawning location versus the age composition of all adults sampled at that mainstem spawning location. No significant differences ($P<0.05$) were found between the age compositions when mainstem spawning locations and adults collected from these locations were combined. No significant differences ($P<0.05$) were found when comparing the age composition of adults released into the spawning channels versus used at the hatchery. No significant differences were found ($P<0.05$) when comparing age composition of adults released into the spawning channels and those sampled in Hamilton Creek. As stated earlier in this document, the only comparisons that returned P values <0.05 were males when comparing the Ives area versus Hamilton Creek and Ives areas versus St. Cloud for females.

K-S tests were used to test for differences in fork lengths of adults released into the spawning channels versus adults spawning naturally in the mainstem Columbia River, adults used at the hatchery and to adults spawning in Hamilton Creek. A summary of this test is presented in **Appendix A** Table 2. For all locations where enough data was available (the K-S test requires at least 10 values in a data set) the only test that returned significantly different ($P=0.004$) when comparing adults released into the spawning channels from a mainstem spawning location versus adults sampled and not used at that mainstem spawning location was for females at the Multnomah area; females used at the channels were larger. No significant differences ($P<0.05$) were found when comparing the fork lengths of adults used at the hatchery versus those placed into the spawning channels at Duncan Creek.

Egg-to-fry survival rates for the two channels, using expected values of AED, were 64% and 58% for the south and north channels respectively. These rates are the highest egg-to-fry survival rates recorded to date for the Duncan Creek spawning channels (Table 25). The egg-to-fry survival rates for both channels in 2004 is close to the expected survival based on the 2002-03 physical habitat sampling, indicating rates could be 60% to 80%.

Table 25. Numbers of adults released, fry totals at each weir and estimated egg-to-fry survival rates at the Duncan Creek Spawning Channels, 2001-2004.

	# Adults released above weir		Fry totals at weir		Egg-to-fry survival rate (%)	
Season	South (M/F)	North (M/F)	South	North	South	North
2001-02	27 (16/11)	16 (8/8)	1,100[1]	7,383[1]	11-17[2]	34-56[2]
2002-03	19 (10/9)	46 (23/23)	9,399	16,079	44[3]	35[3]
2003-04	16 (8/8)	38 (19/19)	15,539	29,911	64	58

[1] Actual counts only, see Hillson (2002) for details.
[2] See Hillson (2002) for explanation of range in rates.
[3] Channels experienced extremes in low and high water levels, see Hillson (2003) for details.

Typical K_D values in chum salmon fry range from 1.8 to 2.0, (the higher the number the more yolk the fry still has present) values of ≤ 1.7 indicate emaciated fry. K_D values can be used to ascertain intra-gravel conditions. Poor intra-gravel conditions may result in premature fry emergence which would be reflected in higher than expected K_D values. No K_D values recorded for fry trapped at the weirs were equal to or below 1.8 in 2004.

Changing to a fence-weir panel fry trap and oversized live boxes in 2003 from the fyke nets and small live boxes used in 2002 reduced the overall trapping related mortality to 0.79%, down from 10.4% in 2002. The majority of mortalities recovered in 2003 were a result of impingement on the fence-weir panels around the sandbags placed to prevent fry from escaping under the panels. Modifications were made to the fence-weir panels in 2004 so that sandbags were not needed on the screens and this appeared to be very effective at reducing impingement related mortality. Overall trapping related mortality was reduced to only 0.19% in 2004.

Releases of marked fry above the weirs were made in 2003 and 2004 to estimate trap efficiency over the course of the outmigration. However, incomplete recovery and fry residing above the traps before out-migrating made the releases useless. Only 29 of the 50 marked fry were reported as recovered during trapping. This resulted in a trap efficiency rate of 64%. Expanding total fry collection by this rate results in a combined expected egg-to-fry survival rate of 93%. Rates this high exceed those in the hatchery, and are not likely from spawning channels. Only a fin clip (upper caudle) was used in 2004 and the importance of recovering these marks was emphasized to all samplers. Placing a long lasting and easily seen mark on fry to assess trap efficiency may not be possible. A combination of dye marking and fin clipping may be used in 2005.

A more complete sampling of females that spawned in the channels and those spawned at Washougal Hatchery resulted in better prediction formulas for PED values and more accurate egg-to-fry survival rates in 2004. A scale was purchased in the spring of 2003 that provided the accuracy (0.001 g) needed to measure individual egg size. Incorporating egg size into the 2003 predictive fecundity regression formulas resulted in a much more accurate estimate.

The steps needed to mark outmigrating fry with strontium were completed prior to the 2004 out-migration, and for the first time naturally-produced salmon fry were marked via immersion in a strontium solution.

Analysis of otoliths recovered from voucher fry for detectable changes in Sr levels showed that a clear and recognizable mark was placed. However, the levels of Sr were lower than personnel at the WDFW

Otolith Lab expected, and are believed to be caused by the short time spent in the marking bath. It is unknown at this time if the marks placed in 2004 will be visible using back-scattered scanning electron imaging. Otolith Lab personnel will evaluate the voucher otoliths using back-scattered scanning electron imaging as soon as access to a scanning electron microscope becomes available (Eric Volk, WDFW Otolith Lab, per. comm.). If the marks are not visible using back-scattered scanning electron imaging, adult recoveries in 2007 through 2009 could only be identified analytically as naturally-produced project origin adults. Given this possibility, an effort will be made in 2005 to increase the Sr marks presence, by either increasing the time in, or increasing the concentration of Sr in the marking bath. Because of logistical constraints on holding time, increasing the concentration of Sr will be explored in 2005.

Uniquely marking the fry produced in the channels will allow estimates of straying rates, both into Duncan Creek by adults produced in other areas, and of Duncan Creek origin adults to other areas. Marking will also allow for an estimate of egg-or fry-to-adult survival rates for naturally-produced fry from the spawning channels.

Channel Modifications and Floodplain Roughening

In the fall of 2003, prior to adults being placed in channels, KPFF Engineering and Crestline Construction repaired damage done during an overland flow event in January 2003 to the top ends of both the middle and north channels. This damage was photo-documented in last years annual report (Hillson 2003). In addition to repairing the damage on the north channel, this channel was extended by approximately 25 feet to capture two more ground water springs that were exposed by erosion caused by the overland flow event in 2003.

In January of 2002 and 2003, severe winter storms resulted in overland flows from Duncan Creek entering the renovated spawning channels (Hillson 2002, 2003). In 2002, a bio-berm was installed at the location where Duncan Creek came out of it's banks following the overland flow event. In January 2003, the water level rose, went around this bio-berm, and again flooded overland into the top of the spawning channels. To prevent this from occurring again, a floodplain-roughing project was executed. This was accomplished by creating four berms, using large logs, in the area between where Duncan Creek has flooded over the past two winters and the channels. The berms were angled to guide any floodwater back into Duncan Creek below the channels. These berms were placed to take advantage of existing standing and downed trees. Logs were then cabled and tied to those existing trees to prevent movement and then backfilled with earth. Several logs were also placed on and around the original bio-berm to reinforce it. The south channel, while not impacted by overland flows in 2002 or 2003, has several old creek beds between it's top and Duncan Creek. Logs were placed into these dry creek beds to protect the south channel. Ten log truckloads of large cottonwood logs, provided by the US Forest Service, were used in this project. All ground disturbed by this work was re-seeded with native grass seed.

Again in 2004, a severe winter storm in January raised the water level sufficiently to cause overland flows from Duncan Creek. This time the water came out farther upstream than it has in the two prior years, the log-reinforced original bio-berm held. However, the overland flow was caught by the second log berm and diverted. No overland flow reached the spawning channels in 2004.

Summary

The Duncan Creek chum salmon project was very successful in 2003-04, providing knowledge and experience that will improve program execution in future years. The gear used to collect adult brood stock was changed from tangle nets to beach seines. This increased efficiency and the speed at which adults could be processed in the field, and most likely reduced stress on the adults handled. Certain weaknesses exposed in past seasons still exist and new ones were exposed (*e.g.* inadequate incubation and rearing space at Washougal Hatchery for any large salvage operation and having to move the rearing troughs outside the raceway in 2004). Egg-to-fry survival rates of 64% and 58% showed that the channels are functioning at the upper end of what can be expected from them. Possibly the most important event this season was the ability to strontium mark and release all naturally-produced fry from the spawning channels. Channel and floodplain modifications reduced the likelihood that floods will damage the channels and negatively impact survival rates.

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Appendix A

Summary tables reporting results of Chi^2 test comparing age composition (Table 1) and K-S tests comparing fork lengths (Table 2) of adults used for brood stock at Washougal Hatchery, adults released into the Duncan Creek spawning channels, adults sampled at mainstem Columbia River spawning sites and adults sampled from Hamilton Creek.

Appendix A. Table 1. Summary of Chi^2 tests comparing age composition.

	Ives versus Ives taken to spawning channels		Multnomah versus Multnomah taken to spawning channels		St Cloud versus St. Cloud taken to spawning channels		Ives versus Ives used as hatchery brood stock		Multnomah versus Multnomah used as hatchery brood stock		St Cloud versus St. Cloud used as hatchery brood stock	
	Chi^2	P value	Chi^2	P value	Chi^2	P value	Chi^2	P value	Chi^2	P value	Chi^2	P value
Males	0.4328	0.8054	0.6973	0.7056	0.5452	0.7614	0.3812	0.8265	1.0153	0.6294	0.4444	0.8007
Females	0.1314	0.9364	0.8938	0.6396	0.4672	0.7917	0.7745	0.6789	0.6019	0.7300	1.4175	0.4923

	Adults from Ives area versus adults from Hamilton Creek		Adults from Ives area versus adults from Multnomah area		Adults from Ives area versus adults from St. Cloud area		Adults from Multnomah area versus adults from Hamilton Creek		Adults from Multnomah area versus adults from St. Cloud area		Adults from St. Cloud area versus adults from Hamilton Creek	
	Chi^2	P value	Chi^2	P value	Chi^2	P value	Chi^2	P value	Chi^2	P value	Chi^2	P value
Males	9.4180	**<u>0.0090</u>**	3.0055	0.2225	0.8400	0.6570	3.4257	0.1804	1.5368	0.4638	4.0449	0.1323
Females	1.6316	0.4423	0.2296	0.8915	6.0311	**<u>0.0490</u>**	1.0014	0.6061	5.0200	0.0813	3.4332	0.1797

	All mainstem locations versus all hatchery brood stock		All mainstem locations versus all spawning channel brood stock		Hatchery brood stock versus spawning channel brood stock		Hamilton Creek versus hatchery brood stock		Hamilton Creek versus spawning channel brood stock	
	Chi^2	P value	Chi^2	P value	Chi^2	P value	Chi^2	P value	Chi^2	P value
Males	1.1938	0.5505	0.1066	0.9481	1.6732	0.4332	6.8968	0.0318	2.2100	0.3312
Females	3.4587	0.1774	0.7866	0.6748	3.3418	0.1881	3.2519	0.1967	1.9286	0.3813

Test returning a significant difference ($P<0.05$) are in **<u>bold and underlined</u>**.

Appendix A. Table 2. Summary of K-S tests comparing fork lengths.

	Hamilton Creek		Ives area		Multnomah area		St. Cloud area		Duncan brood stock		Hatchery brood stock	
Males	D Value	P Value	D Value	P Value	D Value	P Value	D Value	P Value	D Value	P Value	D Value	P Value
Hamilton Creek	------------	------------	0.0934	0.435	0.1248	0.084	0.0870	0.954	0.2089	0.240	0.1351	0.606
Ives area	0.0934	0.435	------------	------------	0.0655	0.624	0.0638	0.982	0.3703	0.053	0.2992	0.072
Multnomah area	0.1248	0.084	0.0655	0.624	------------	------------	0.0916	0.733	NA	NA	NA	NA
St. Cloud area	0.0870	0.954	0.0638	0.982	0.0916	0.733	------------	------------	0.2372	0.689	0.1825	0.858
Duncan brood stock	0.2089	0.240	0.3703	0.053	NA	NA	0.2372	0.689	------------	------------	0.2836	0.130
Hatchery brood stock	0.1351	0.606	0.2992	0.072	NA	NA	0.1825	0.858	0.2836	0.130	------------	------------

	Hamilton Creek		Ives area		Multnomah area		St. Cloud area		Duncan brood stock		Hatchery brood stock	
Females	D Value	P Value	D Value	P Value	D Value	P Value	D Value	P Value	D Value	P Value	D Value	P Value
Hamilton Creek	------------	------------	0.1425	0.100	0.1183	0.182	0.2567	**0.034**	0.3231	**0.016**	0.3047	**0.008**
Ives area	0.1425	0.100	------------	------------	0.0780	0.598	0.3343	**0.001**	NA	NA	NA	NA
Multnomah area	0.1183	0.182	0.0780	0.598	------------	------------	0.2158	**0.023**	0.4815	**0.004**	0.3206	**0.042**
St. Cloud area	0.2567	**0.034**	0.3343	**0.001**	0.2158	**0.023**	------------	------------	0.3612	0.169	na	na
Duncan brood stock	0.3231	**0.016**	NA	NA	0.4815	**0.004**	0.3612	0.169	------------	------------	0.2393	0.309
Hatchery brood stock	0.3047	**0.008**	NA	NA	0.3206	**0.042**	na	na	0.2393	0.309	------------	------------

Test returning a significant difference ($P<0.05$) are in **bold and underlined**.
NA = less than 10 data points in data set.
When comparing a single mainstem area to brood stock (both for the hatchery and spawning channel) only brood stock collected from that area were compared.
When comparing a single mainstem area or brood stock (both hatchery and spawning channel) to Hamilton Creek all adults from that area or brood stock were used.

Appendix B

Summary table reporting average daily temperatures recorded by Tidbit recorders in the Duncan Creek spawning channels (Table 1).

Appendix B. Table 1. Daily average water temperatures recorded by Tidbit data loggers placed in Duncan Creek Spawning Channels, November 4, 2003 to April 28, 2004.

	South channel						Middle channel						North channel					
	Mid water	Sub-surface				Mid water	Mid water	Sub-surface				Mid water	Mid water	Sub-surface				Mid water
Date	top	#1	#2	#3	#4	bottom	top	#1	#2	#3	#4	bottom	top	#1	#2	#3	#4	bottom
11/4	3.7	5.2	6.5	6.2	6.4		8.2	9.2	8.5		8.2	7.8	5.3	5.3	5.3		8.9	5.3
11/5	4.2	5.0	6.1	6.0	5.6		6.9	9.0	8.0		7.8	5.9	8.7	9.0	8.7		8.7	8.7
11/6	5.2	5.0	5.6	5.9	5.1		5.6	8.3	7.3		7.6	5.7	8.5	8.6	8.4		8.4	8.3
11/7	5.7	5.5	5.6	6.1	5.6		6.1	7.9	7.3		7.6	6.0	8.5	8.5	8.3		8.3	8.3
11/8	7.0	6.1	5.9	6.3	6.1		7.1	7.1	7.9		7.6	7.0	8.5	8.4	8.2		8.2	8.1
11/9	7.7	7.3	7.0	7.4	7.6		7.9	7.5	8.6		8.5	7.9	8.9	8.8	8.6		8.6	8.8
11/10	8.3	7.5	7.4	7.7	7.8		8.5	7.5	8.9		9.0	8.3	9.0	8.9	8.7		8.8	8.9
11/11	9.8	8.8	8.6	8.9	9.3		9.4	9.0	9.2		9.3	9.5	9.4	9.2	9.1		9.5	9.4
11/12	7.5	8.5	8.7	8.4	9.3		9.2	9.2	9.1		9.0	9.0	9.4	9.3	9.2		9.4	9.4
11/13	7.5	9.1	7.9	8.1	9.2		9.1	9.2	9.1		8.8	8.8	9.3	9.3	9.1		9.3	9.3
11/14	8.2	9.2	8.4	8.3	9.3		9.2	9.2	9.2		9.1	9.0	9.3	9.4	9.2		9.4	9.3
11/15	6.6	8.7	8.7	8.2	9.2		9.2	9.2	9.2		9.1	9.0	9.3	9.4	9.1		9.4	9.3
11/16	7.7	9.3	8.9	8.4	9.2		9.3	9.2	9.3		9.2	9.1	9.4	9.4	9.1		9.6	9.4
11/17	8.8	9.3	9.2	9.1	9.1		9.3	9.2	9.3		9.3	9.2	9.5	9.5	9.2		9.6	9.5
11/18	9.4	9.4	9.2	9.4	9.3		9.3	9.3	9.3		9.5	9.3	9.6	9.6	9.2		9.6	9.5
11/19	9.3	9.4	9.3	9.2	9.1		9.3	9.3	9.3		9.3	9.1	9.6	9.6	9.2		9.4	9.4
11/20	9.3	9.4	9.3	9.2	9.2		9.3	9.3	9.3		9.2	9.1	9.6	9.6	9.1		9.3	9.3
11/21	9.1	9.4	9.3	9.1	9.1		9.3	9.3	9.3		9.2	9.0	9.5	9.6	8.9		9.3	9.1
11/22	9.1	9.4	9.3	9.1	9.1		9.3	9.3	9.3		9.2	9.0	9.5	9.5	8.9		9.1	9.0
11/23	8.9	9.5	9.4	9.2	9.2		9.4	9.3	9.3		9.3	9.2	9.5	9.5	8.8		9.1	9.1
11/24	8.9	9.6	9.4	9.2	9.2		9.3	9.3	9.3		9.2	9.1	9.4	9.4	8.6		9.0	8.9
11/25	9.2	9.6	9.5	9.2	9.2		9.3	9.3	9.3		9.3	9.1	9.3	9.3	8.5		8.9	8.8
11/26	9.4	9.6	9.5	9.3	9.3		9.3	9.3	9.4		9.3	9.2	9.3	9.3	8.4		8.8	8.7
11/27	9.5	9.6	9.6	9.3	9.2		9.3	9.3	9.4		9.3	9.1	9.2	9.3	8.4		8.8	8.7
11/28	9.6	9.7	9.6	9.4	9.3		9.4	9.3	9.4		9.3	9.2	9.1	9.2	8.3		8.6	8.7
11/29	9.7	9.7	9.6	9.6	9.6		9.4	9.3	9.4		9.5	9.4	9.1	9.1	8.1		8.5	8.5
11/30	9.6	9.7	9.6	9.5	9.4		9.3	9.3	9.4		9.4	9.3	8.9	9.0	8.3		8.5	8.6
12/1	9.5	9.7	9.6	9.3	9.3		9.3	9.3	9.4		9.2	9.1	8.8	8.9	8.3		8.4	8.4
12/2	9.7	9.7	9.6	9.4	9.4		9.3	9.3	9.4		9.3	9.2	8.8	8.8	8.1		8.4	8.4
12/3	9.6	9.7	9.6	9.4	9.3		9.3	9.3	9.4		9.3	9.2	8.6	8.7	8.0		8.3	8.3
12/4	8.9	9.6	9.6	9.0	8.9		9.2	9.3	9.4		8.9	8.8	8.6	8.7	8.3		8.2	8.2
12/5	9.4	9.6	9.6	9.2	9.2		9.3	9.3	9.4		9.1	9.0	8.5	8.7	8.0		8.2	8.3
12/6	9.6	9.6	9.6	9.5	9.4		9.2	9.3	9.4		9.3	9.2	8.5	8.6	7.8		8.2	8.2
12/7	9.6	9.7	9.6	9.4	9.4		9.1	9.2	9.4		9.2	9.1	8.4	8.5	7.7		8.1	8.0
12/8	9.6	9.7	9.6	9.5	9.4		9.1	9.2	9.4		9.3	9.2	8.5	8.5	7.7		8.1	8.0
12/9	9.4	9.6	9.6	9.2	9.1		9.1	9.2	9.4		9.1	8.9	8.4	8.5	8.1		8.0	8.1
12/10	9.5	9.6	9.6	9.2	9.1		9.1	9.2	9.4		9.0	8.9	8.4	8.4	7.8		8.0	8.1
12/11	9.1	9.6	9.6	9.2	9.1		9.1	9.2	9.4		9.1	8.9	8.3	8.4	7.8		8.1	8.1
12/12	8.8	9.6	9.6	9.1	9.1		9.1	9.2	9.4		9.0	8.9	8.3	8.4	7.7		8.1	8.1
12/13	9.2	9.5	9.5	9.2	9.1		9.0	9.2	9.3		9.1	8.9	8.2	8.4	7.6		8.0	8.0
12/14	9.5	9.5	9.4	9.4	9.3		9.0	9.1	9.3		9.1	9.1	8.2	8.2	7.5		8.0	8.0
12/15	9.5	9.6	9.3	9.4	9.3		9.0	9.0	9.3		9.1	9.1	8.1	8.2	7.5		7.9	7.9
12/16	9.4	9.6	9.3	9.3	9.2		9.0	9.0	9.3		8.9	8.9	8.0	8.1	7.5		7.8	7.8
12/17	9.4	9.6	9.3	9.2	9.1		9.0	9.0	9.3		9.0	8.9	8.0	8.1	7.5		7.9	7.8
12/18	9.0	9.4	9.3	8.9	8.8		8.8	9.0	9.3		8.7	8.5	8.0	8.2	7.8		7.7	7.7
12/19	8.6	9.4	9.3	8.8	8.7		8.8	9.0	9.2		8.6	8.5	8.0	8.2	7.9		7.8	7.8
12/20	9.1	9.5	9.3	9.1	9.0		8.9	9.0	9.2		8.9	8.8	8.0	8.2	7.6		7.9	8.0
12/21	9.2	9.5	9.3	9.2	9.1		8.8	9.0	9.1		9.0	8.8	8.1	8.2	7.5		8.0	8.0
12/22	9.0	9.4	9.2	9.0	9.1		9.1	9.1	9.3		9.1	9.0	8.8	8.9	8.3		8.6	8.6
12/23	6.8	9.3	8.9	8.6	8.6		8.8	9.0	9.1		8.6	8.3	8.1	8.2	8.0		7.9	7.9
12/24	5.9	9.3	9.0	8.9	8.8		8.8	9.0	9.1		8.8	8.6	8.1	8.2	7.8		8.0	8.1
12/25	8.0	9.3	9.0	8.9	8.8		8.8	9.0	9.1		8.8	8.6	8.1	8.2	7.6		8.0	8.0

Appendix B. Table 1. Continued

	South channel						Middle channel						North channel					
	Mid water	Sub-surface				Mid water	Mid water	Sub-surface				Mid water	Mid water	Sub-surface				Mid water
Date	top	#1	#2	#3	#4	bottom	top	#1	#2	#3	#4	bottom	top	#1	#2	#3	#4	bottom
12/26	8.1	9.3	9.1	8.9	8.8		8.8	9.0	9.1		8.8	8.7	8.1	8.2	7.6		8.0	8.0
12/27	7.6	9.2	9.1	8.7	8.6		8.8	9.0	9.1		8.7	8.5	8.0	8.2	7.6		7.9	7.9
12/28	8.6	9.3	9.2	8.8	8.8		8.8	8.9	9.1		8.8	8.6	8.0	8.2	7.6		7.9	7.9
12/29	8.3	9.1	9.2	8.4	8.4		8.8	8.8	9.1		8.4	8.2	7.9	8.1	7.8		7.8	7.8
12/30	8.4	9.0	9.2	8.3	8.3		8.8	8.8	9.1		8.3	8.1	7.8	8.1	7.7		7.7	7.8
12/31	7.6	8.9	9.2	8.3	8.3		8.8	8.8	9.1		8.2	8.1	7.9	8.1	7.7		7.8	7.9
1/1	7.0	8.8	9.0	8.2	8.1		8.8	8.8	9.1		8.2	8.0	7.9	8.1	7.7		7.7	7.7
1/2	7.7	9.1	8.7	8.6	8.6		8.8	8.8	9.1		8.6	8.4	8.0	8.1	7.6		7.9	8.0
1/3	7.4	9.1	8.7	8.5	8.5		8.8	8.8	9.0		8.6	8.4	8.0	8.1	7.6		7.8	7.9
1/4	4.3	9.0	8.1	7.4	7.7		8.8	8.8	9.0		7.7	7.4	7.7	8.0	7.7		7.6	7.4
1/5	0.0	8.8	7.5	6.4	7.1		8.8	8.8	9.0		7.0	6.7	7.7	7.9	7.5		7.3	7.0
1/6	-0.8	8.8	7.1	4.8	6.0		8.7	8.8	9.0		5.8	5.4	7.4	7.5	7.2		6.8	6.5
1/7	1.7	8.4	7.8	6.2	6.6		8.8	8.8	9.0		6.2	6.4	7.5	7.8	7.4		7.3	7.1
1/8	5.2	8.6	8.0	7.4	7.6		8.8	8.8	9.0		7.4	7.2	7.7	7.9	7.6		7.5	7.4
1/9	6.3	8.8	8.1	7.6	7.9		8.8	8.8	9.0		7.7	7.6	7.8	8.0	7.7		7.6	7.6
1/10	7.3	8.8	8.2	8.0	8.1		8.8	8.8	9.0		8.1	8.1	7.9	8.1	7.8		7.7	7.9
1/11	7.1	8.8	8.2	7.9	8.0		8.8	8.8	9.0		8.0	7.9	7.9	8.1	7.8		7.7	7.7
1/12	7.0	8.8	8.2	7.9	8.0		8.8	8.8	9.0		8.0	7.9	7.9	8.1	7.8		7.7	7.7
1/13	7.2	8.8	8.2	7.9	8.0		8.8	8.8	9.0		8.1	8.0	7.9	8.1	7.9		7.7	7.8
1/14	7.1	8.7	8.2	7.9	8.0		8.8	8.8	9.0		8.0	8.0	7.9	8.1	7.8		7.7	7.7
1/15	7.8	8.7	8.6	8.3	8.2		8.8	8.8	9.0		8.3	8.3	7.9	8.1	7.5		7.7	7.7
1/16	8.1	8.8	8.8	8.2	8.2		8.8	8.8	9.0		8.4	8.2	7.8	8.1	7.4		7.6	7.7
1/17	8.3	8.8	8.8	8.2	8.1		8.7	8.8	9.0		8.2	8.1	7.7	7.9	7.5		7.6	7.6
1/18	8.6	8.7	8.8	8.3	8.2		8.7	8.8	9.0		8.4	8.2	7.6	7.9	7.3		7.5	7.6
1/19	8.3	8.7	8.8	8.4	8.3		8.7	8.8	9.0		8.4	8.3	7.6	7.9	7.2		7.4	7.6
1/20	8.3	8.7	8.8	8.3	8.2		8.7	8.7	9.0		8.2	8.1	7.4	7.8	7.2		7.3	7.5
1/21	8.5	8.7	8.7	8.3	8.2		8.7	8.7	9.0		8.3	8.1	7.4	7.7	7.2		7.3	7.5
1/22	8.5	8.7	8.7	8.3	8.3		8.7	8.7	9.0		8.3	8.2	7.4	7.6	7.2		7.3	7.5
1/23	8.4	8.5	8.7	8.3	8.2		8.7	8.7	9.0		8.3	8.1	7.2	7.5	6.9		7.2	7.4
1/24	8.3	8.1	8.7	8.0	8.0		8.6	8.7	9.0		8.2	7.9	6.8	7.3	6.7		7.0	7.1
1/25	8.2	8.3	8.7	8.2	8.2		8.5	8.7	8.9		8.3	8.2	6.7	7.3	6.6		6.9	7.0
1/26	8.2	8.4	8.7	8.3	8.3		8.4	8.6	8.8		8.4	8.2	6.6	7.1	6.5		6.7	6.8
1/27	8.1	8.4	8.6	8.3	8.2		8.4	8.5	8.8		8.3	8.2	6.6	6.9	6.4		6.8	6.7
1/28	8.0	8.4	8.5	8.3	8.2		8.4	8.5	8.8		8.4	8.3	6.4	6.8	6.3		6.8	6.8
1/29	7.9	8.3	8.4	8.3	8.1		8.3	8.5	8.8		8.2	8.1	6.1	6.7	6.2		6.7	6.8
1/30	7.8	8.2	8.4	8.2	8.0		8.1	8.4	8.3		8.0	7.9	5.9	6.5	6.2		6.6	6.7
1/31	7.7	8.2	8.4	8.0	7.9		8.1	8.3	8.3		8.0	7.9	6.0	6.6	6.2		6.6	6.6
2/1	7.8	8.2	8.4	8.0	7.9		8.1	8.2	8.4		8.0	7.9	6.1	6.6	6.4		6.8	6.8
2/2	7.7	7.9	8.4	7.8	7.7		8.1	8.2	8.4		7.8	7.7	6.1	6.5	6.5		6.7	6.7
2/3	7.6	8.0	8.4	7.8	7.8		8.1	8.2	8.6		8.0	7.8	6.2	6.5	6.6		6.7	6.7
2/4	7.6	8.1	8.4	7.8	7.8		8.2	8.2	8.5		8.1	7.9	6.3	6.6	6.6		6.8	6.9
2/5	7.6	8.1	8.4	7.8	7.8		8.2	8.4	8.5		8.0	7.7	6.4	6.8	6.8		6.9	6.9
2/6	7.7	8.0	8.4	7.8	7.8		8.2	8.4	8.6		8.0	7.8	6.6	6.8	6.8		7.0	7.0
2/7	7.8	8.1	8.4	7.9	7.9		8.4	8.4	8.6		8.1	7.9	6.7	6.9	6.9		7.1	7.1
2/8	7.8	8.0	8.4	7.9	7.9		8.4	8.5	8.7		8.2	7.9	6.9	7.1	6.9		7.2	7.2
2/9	7.9	8.1	8.5	7.9	7.9		8.4	8.5	8.7		8.1	7.9	7.0	7.2	7.1		7.3	7.3
2/10	7.9	8.1	8.5	7.9	7.9		8.5	8.5	8.7		8.1	7.9	7.1	7.3	7.3		7.4	7.4
2/11	7.9	8.1	8.5	7.9	7.9		8.5	8.7	8.7		8.1	7.9	7.2	7.4	7.4		7.5	7.4
2/12	7.9	8.1	8.5	7.9	7.9		8.5	8.7	8.7		8.0	7.8	7.4	7.5	7.5		7.5	7.5
2/13	7.9	8.1	8.6	7.8	7.8		8.5	8.7	8.7		8.0	7.8	7.4	7.5	7.5		7.5	7.4
2/14	7.9	8.2	8.6	8.0	7.9		8.5	8.7	8.8		8.3	8.0	7.5	7.6	7.6		7.6	7.6
2/15	8.0	8.3	8.7	8.1	8.0		8.5	8.7	8.8		8.4	8.1	7.6	7.7	7.6		7.7	7.7

Appendix B. Table 1. Continued

	South channel						Middle channel						North channel					
	Mid water	Sub-surface				Mid water	Mid water	Sub-surface				Mid water	Mid water	Sub-surface				Mid water
Date	top	#1	#2	#3	#4	bottom	top	#1	#2	#3	#4	bottom	top	#1	#2	#3	#4	bottom
2/16	7.9	8.3	8.7	8.0	8.0		8.6	8.7	8.8		8.2	8.0	7.6	7.8	7.6		7.7	7.7
2/17	7.9	8.2	8.7	8.0	8.0		8.7	8.7	8.8		8.3	8.0	7.6	7.8	7.6		7.6	7.7
2/18	7.9	8.2	8.7	8.1	8.1		8.7	8.8	8.8		8.4	8.1	7.7	7.8	7.6		7.7	7.8
2/19	8.0	8.2	8.7	8.1	8.0		8.7	8.8	8.8		8.5	8.1	7.7	7.8	7.5		7.6	7.7
2/20	7.9	8.2	8.7	8.0	8.0		8.7	8.8	8.8		8.4	8.0	7.6	7.8	7.6		7.7	7.8
2/21	7.9	8.3	8.7	8.0	8.0		8.7	8.8	8.8		8.3	8.1	7.6	7.8	7.7		7.8	7.7
2/22	7.9	8.2	8.7	8.0	8.0		8.7	8.8	8.8		8.4	8.1	7.6	7.8	7.7		7.7	7.7
2/23	7.9	8.3	8.6	8.1	8.0		8.7	8.8	8.8		8.5	8.1	7.6	7.8	7.7		7.7	7.8
2/24	7.9	8.3	8.5	8.1	8.0		8.7	8.8	8.8		8.5	8.1	7.6	7.8	7.7		7.7	7.8
2/25	7.9	8.4	8.5	8.0	7.9		8.7	8.8	8.8		8.3	8.0	7.6	7.8	7.6		7.7	7.8
2/26	7.9	8.3	8.5	8.0	8.0		8.7	8.8	8.8		8.5	8.1	7.7	7.9	7.7		7.8	7.8
2/27	7.9	8.3	8.5	8.1	8.0		8.7	8.8	8.8		8.5	8.2	7.8	7.9	7.6		7.9	7.8
2/28	7.9	8.4	8.5	8.1	8.0		8.7	8.8	8.9		8.6	8.2	7.8	7.9	7.5		7.9	7.9
2/29	8.0	8.4	8.5	8.1	8.0		8.7	8.8	8.9		8.6	8.2	7.8	8.0	7.7		8.0	7.9
3/1	8.0	8.4	8.6	8.1	8.1		8.7	8.8	8.8		8.6	8.3	7.8	8.0	7.9		8.1	8.0
3/2	8.0	8.3	8.5	8.1	8.1		8.7	8.8	8.9		8.7	8.3	7.9	8.1	7.9		8.1	8.0
3/3	7.9	8.2	8.5	8.0	8.0		8.7	8.8	8.8		8.5	8.1	7.9	8.0	7.7		8.0	8.0
¾	7.9	8.2	8.5	8.0	8.0		8.7	8.8	8.8		8.5	8.1	7.9	8.1	7.7		8.1	8.0
3/5	7.9	8.2	8.5	8.0	8.0		8.7	8.8	8.9		8.5	8.1	7.9	8.1	7.6		8.0	7.9
3/6	8.0	8.3	8.5	8.1	8.1		8.7	8.8	8.9		8.6	8.2	7.9	8.1	7.8		8.1	8.1
3/7	8.0	8.3	8.5	8.2	8.1		8.7	8.8	8.9		8.7	8.3	8.0	8.1	7.8		8.1	8.1
3/8	8.1	8.4	8.5	8.2	8.2		8.7	8.8	8.9		8.7	8.4	8.0	8.1	8.1		8.2	8.3
3/9	8.0	8.4	8.5	8.2	8.1		8.7	8.8	8.9		8.7	8.3	8.0	8.1	7.9		8.1	8.1
3/10	8.0	8.3	8.5	8.1	8.2		8.7	8.8	8.9		8.7	8.3	8.0	8.1	8.1		8.2	8.1
3/11	8.0	8.3	8.5	8.2	8.2		8.7	8.8	8.9		8.6	8.3	8.0	8.2	8.2		8.2	8.2
3/12	8.0	8.3	8.5	8.2	8.2		8.7	8.8	8.9		8.7	8.3	8.1	8.1	8.1		8.2	8.2
3/13	8.0	8.3	8.5	8.2	8.2		8.7	8.8	8.9		8.6	8.3	8.1	8.2	8.2		8.2	8.3
3/14	8.0	8.4	8.5	8.2	8.3		8.8	8.8	8.9		8.8	8.4	8.1	8.2	8.1		8.3	8.3
3/15	8.1	8.4	8.5	8.3	8.3		8.8	8.8	8.9		8.8	8.5	8.2	8.3	8.3		8.3	8.4
3/16	8.3	8.4	8.5	8.3	8.3		8.8	8.8	8.8		8.9	8.5	8.2	8.3	8.3		8.4	8.5
3/17	8.3	8.4	8.5	8.3	8.3		8.8	8.8	8.9		8.9	8.5	8.2	8.4	8.2		8.4	8.4
3/18	8.3	8.4	8.5	8.2	8.2		8.8	8.8	8.9		8.6	8.4	8.2	8.4	8.1		8.3	8.3
3/19	8.3	8.4	8.5	8.3	8.3		8.8	8.8	8.9		8.8	8.4	8.2	8.4	8.3		8.5	8.3
3/20	8.3	8.4	8.5	8.3	8.3		8.8	8.8	8.9		8.6	8.4	8.3	8.4	8.5		8.5	8.5
3/21	8.3	8.5	8.5	8.4	8.4		8.8	8.8	8.9		8.8	8.6	8.3	8.5	8.6		8.6	8.6
3/22	8.4	8.5	8.5	8.4	8.5		8.8	8.8	8.9		8.9	8.7	8.3	8.5	8.6		8.6	8.6
3/23	8.5	8.5	8.5	8.5	8.5		8.8	8.8	8.9		9.0	8.7	8.4	8.5	8.6		8.6	8.7
3/24	8.5	8.5	8.5	8.3	8.3		8.8	8.8	8.9		8.8	8.5	8.3	8.5	8.5		8.6	8.5
3/25	8.4	8.5	8.5	8.3	8.2		8.8	8.8	8.9		8.6	8.4	8.3	8.5	8.3		8.5	8.4
3/26	8.4	8.5	8.5	8.3	8.3		8.8	8.8	8.9		8.8	8.5	8.3	8.5	8.4		8.6	8.5
3/27	8.4	8.5	8.5	8.3	8.3		8.8	8.8	9.0		8.8	8.5	8.4	8.5	8.4		8.5	8.5
3/28	8.5	8.5	8.5	8.4	8.5		8.8	8.8	9.0		8.9	8.7	8.4	8.6	8.8		8.7	8.7
3/29	8.5	8.6	8.5	8.5	8.5		8.9	8.8	9.0		8.9	8.8	8.5	8.6	8.8		8.7	8.8
3/30	8.3	8.5	8.5	8.4	8.3		8.8	8.8	9.0		8.8	8.5	8.4	8.6	8.5		8.5	8.5
3/31	8.3	8.5	8.5	8.4	8.4		8.9	8.8	9.0		8.9	8.6	8.4	8.6	8.7		8.6	8.7
4/1	8.4	8.5	8.5	8.4	8.5		8.9	8.8	9.0		8.9	8.7	8.5	8.7	8.8		8.7	8.6
4/2	8.4	8.5	8.5	8.5	8.6		8.8	8.8	8.9		9.0	8.8	8.5	8.7	8.9		8.7	8.8
4/3	8.4	8.5	8.5	8.7	8.8		8.8	8.8	8.9		9.1	8.9	8.5	8.8	8.9		8.8	8.8
4/4	8.4	8.5	8.5	8.6	8.6		8.8	8.8	8.9		9.0	8.8	8.6	8.8	8.9		8.8	8.8
4/5	8.4	8.5	8.5	8.5	8.5		8.8	8.8	8.9		8.9	8.7	8.4	8.7	8.7		8.7	8.7
4/6	8.4	8.5	8.5	8.7	8.7		8.8	8.8	8.8		9.0	8.9	8.5	8.8	8.8		8.8	8.8
4/7	8.3	8.5	8.5	8.6	8.6		8.8	8.8	8.8		8.9	8.8	8.5	8.7	8.7		8.7	8.7

Appendix B Table 1. Continued

	South channel						Middle channel						North channel					
	Mid water	Sub-surface				Mid water	Mid water	Sub-surface				Mid water	Mid water	Sub-surface				Mid water
Date	top	#1	#2	#3	#4	bottom	top	#1	#2	#3	#4	bottom	top	#1	#2	#3	#4	bottom
4/8	8.3	8.5	8.5	8.7	8.7		8.8	8.8	8.8		8.9	8.9	8.6	8.8	8.8		8.8	8.8
4/9	8.3	8.5	8.6	8.8	8.8		8.8	8.8	8.8		9.1	9.0	8.6	8.8	9.0		8.9	8.9
4/10	8.3	8.5	8.7	8.9	8.9		8.9	8.8	8.8		9.1	9.1	8.6	8.8	9.0		9.0	8.9
4/11	8.2	8.5	8.7	8.9	8.9		8.9	8.8	8.8		9.2	9.2	8.6	8.8	9.1		9.0	8.9
4/12	8.2	8.4	8.6	8.8	8.8		8.8	8.8	8.8		9.0	9.0	8.6	8.8	9.0		8.9	8.8
4/13	8.2	8.4	8.6	8.8	8.7		8.8	8.8	8.8		9.0	9.0	8.5	8.8	8.9		8.9	8.8
4/14	8.2	8.4	8.4	8.6	8.6		8.8	8.8	8.8		8.9	8.8	8.5	8.8	8.8		8.7	8.7
4/15	8.2	8.4	8.4	8.6	8.5		8.8	8.8	8.8		8.9	8.8	8.5	8.8	8.7		8.8	8.7
4/16	8.2	8.4	8.6	8.8	8.8		8.8	8.8	8.8		9.2	9.1	8.6	8.8	8.9		8.9	8.9
4/17	8.2	8.5	8.6	8.8	8.8		8.8	8.8	8.8		9.0	9.0	8.6	8.9	8.9		8.9	8.9
4/18	8.2	8.5	8.5	8.7	8.7		8.8	8.8	8.8		9.0	8.9	8.6	8.9	8.9		8.9	8.9
4/19	8.2	8.5	8.5	8.7	8.7		8.8	8.8	8.8		8.9	8.8	8.6	8.8	8.9		8.9	8.9
4/20	8.2	8.4	8.4	8.5	8.5		8.8	8.8	8.8		8.9	8.7	8.6	8.8	8.7		8.8	8.8
4/21	8.1	8.5	8.5	8.8	8.8		8.8	8.9	8.8		8.9	9.0	8.6	8.8	8.9		9.0	9.0
4/22	8.1	8.5	8.6	8.9	8.9		8.9	8.9	8.8		8.9	9.2	8.7	8.9	9.1		9.1	9.1
4/23	8.2	8.5	8.4	8.6	8.6		8.8	8.9	8.8		8.8	8.8	8.6	8.9	8.9		8.9	8.9
4/24	8.2	8.6	8.6	8.8	8.8		8.8	8.9	8.8		8.8	9.1	8.6	8.9	9.1		9.1	9.1
4/25	8.4	8.7	8.7	9.1	9.1		8.9	8.9	8.8		9.0	9.4	8.7	8.9	9.1		9.2	9.2
4/26	8.8	8.8	8.9	9.4	9.3		8.9	8.9	8.8		9.2	9.5	8.7	8.9	9.2		9.3	9.2
4/27	9.0	8.6	8.8	9.3	9.2		8.9	9.0	8.8		9.1	9.4	8.6	9.0	9.1		9.2	9.2
4/28	9.2	8.6	8.8	9.4	9.2		8.9	9.0	8.8		9.2	9.5	8.6	9.0	9.1		9.2	9.4

Appendix C

Summary tables reporting daily collection of salmonids and daily percent mortality for age 0+ chum at the two weirs in Duncan Creek (Table 1), and daily totals of strontium marked fry placed into the marking bath, mortality in the marking bath, number of strontium marked fry released daily and results of the 48 hour delayed mortality study (Table 2), 2004.

Appendix C. Table 1. Daily collection numbers of salmonids and daily percent mortality for age 0+ chum salmon at the two weirs in the Duncan Creek Spawning Channels, 2004.

	South weir							North weir						
	Chum				Coho		Other	Chum				Coho		Other
	Age 0+				Age 0+	Age 1+		Age 0+				Age 0+	Age 1+	
Date	Live	Dead	Total	% Mort	Total	Total		Live	Dead	Total	% Mort	Total	Total	
27-Feb	0	0	0					0	0	0				
28-Feb	0	0	0			2		0	0	0				
29-Feb	0	0	0					0	0	0				
1-Mar	0	0	0					0	0	0				
2-Mar	0	0	0					0	0	0				
3-Mar	0	0	0			2		0	0	0				
4-Mar	0	0	0					0	0	0				
5-Mar	0	0	0					0	0	0				
6-Mar	0	0	0					0	0	0				
7-Mar	0	0	0					0	0	0				
8-Mar	0	0	0			1		0	0	0				
9-Mar	0	0	0					0	0	0				
10-Mar	1	0	1	0.0%				0	0	0				
11-Mar	0	0	0					0	0	0				
12-Mar	5	0	5	0.0%			Cutthroat-200 mm	0	0	0				
13-Mar	6	0	6	0.0%				0	0	0				
14-Mar	10	0	10	0.0%				0	0	0				
15-Mar	35	0	35	0.0%				16	1	17	6.3%			
16-Mar	131	0	131	0.0%			Hatch STHD-189 mm	41	0	41	0.0%			
17-Mar	300	2	302	0.7%				69	1	70	1.4%			
18-Mar	570	1	571	0.2%				60	0	60	0.0%			
19-Mar	1,048	7	1,055	0.7%			Cutthroat-121 mm	172	4	176	2.3%			
20-Mar	493	1	494	0.2%				93	1	94	1.1%			
21-Mar	470	0	470	0.0%		1		28	0	28	0.0%			
22-Mar	948	3	951	0.3%				2	0	2	0.0%			
23-Mar	927	2	929	0.2%				263	0	263	0.0%			
24-Mar	470	0	470	0.0%				569	0	569	0.0%			
25-Mar	669	2	671	0.3%		1		546	0	546	0.0%			
26-Mar	337	0	337	0.0%				1,735	2	1,737	0.1%		2	
27-Mar	449	0	449	0.0%				2,350	2	2,352	0.1%		3	

Appendix C. Table 1. Continued

	South weir							North weir						
	Chum				Coho		Other	Chum				Coho		Other
	Age 0+				Age 0+	Age 1+		Age 0+				Age 0+	Age 1+	
Date	Live	Dead	Total	% Mort	Total	Total		Live	Dead	Total	% Mort	Total	Total	
28-Mar	728	0	728	0.0%				1,644	2	1,646	0.1%			
29-Mar	836	0	836	0.0%		3	Rainbow –239 mm	1,309	3	1,312	0.2%			
30-Mar	530	1	531	0.2%			3 RBT-133, 129, 92 mm	574	0	574	0.0%		1	
31-Mar	815	0	815	0.0%			Hatch STHD-150 mm	731	1	732	0.1%			
1-Apr	728	1	729	0.1%		2		716	0	716	0.0%			
2-Apr	895	0	895	0.0%				1,126	4	1,130	0.4%			
3-Apr	505	0	505	0.0%				584	2	586	0.3%			
4-Apr	204	1	205	0.5%				695	2	697	0.3%			
5-Apr	252	0	252	0.0%				1,265	1	1,266	0.1%			
6-Apr	214	3	217	1.4%				1,390	2	1,392	0.1%			
7-Apr	334	0	334	0.0%				914	2	916	0.2%			
8-Apr	280	0	280	0.0%				947	1	948	0.1%			
9-Apr	185	0	185	0.0%				456	3	459	0.7%			
10-Apr	197	1	198	0.5%				675	1	676	0.1%			
11-Apr	101	0	101	0.0%				375	1	376	0.3%			
12-Apr	76	0	76	0.0%				343	0	343	0.0%			
13-Apr	116	0	116	0.0%		1		894	4	898	0.4%			
14-Apr	81	0	81	0.0%				1,531	4	1,535	0.3%			
15-Apr	103	4	107	3.9%				2,081	1	2,082	0.0%			
16-Apr	61	0	61	0.0%				1,859	2	1,861	0.1%			
17-Apr	102	0	102	0.0%	1			588	2	590	0.3%			
18-Apr	353	1	354	0.3%				847	0	847	0.0%			
19-Apr	53	0	53	0.0%				195	1	196	0.5%			
20-Apr	91	0	91	0.0%				223	1	224	0.4%			
21-Apr	18	0	18	0.0%				119	0	119	0.0%			
22-Apr	69	0	69	0.0%				78	0	78	0.0%			
23-Apr	50	0	50	0.0%				36	0	36	0.0%			
24-Apr	14	0	14	0.0%				40	0	40	0.0%			
25-Apr	76	1	77	1.3%				14	0	14	0.0%			
26-Apr	12	1	13	8.3%	1			70	0	70	0.0%			

Appendix C. Table 1. Continued

	South weir							North weir						
	Chum				Coho		Other	Chum				Coho		Other
	Age 0+				Age 0+	Age 1+		Age 0+				Age 0+	Age 1+	
Date	Live	Dead	Total	% Mort	Total	Total		Live	Dead	Total	% Mort	Total	Total	
27- Apr	31	0	31	0.0%	4			40	1	41	2.5%		1	
28- Apr	5	0	5	0.0%	2	2		20	0	20	0.0%			
Seining														
4/27	479	2	481	0.4%	8	15		1,482	1	1,483	0.1%		7	
4/28	42	0	42	0.0%	8	15		52	1	53	1.9%		7	
Total	15,505	34	15,539	0.22%				29,857	54	29,911	0.18%			

Appendix C. Table 2. Daily totals for strontium marking of age-0+ chum salmon at the Duncan Creek Spawning Channels, 2004.

		Strontium marking bath			Delayed mortality test					
					# Held in each group		# Morts recovered			
Date	Daily collection (minus morts)	# Added	# Morts	# Removed	Test	Control	Test	Control	# Voucher fry removed from test group	Daily # released
27-Feb	0	0	0	0						0
28-Feb	0	0	0	0						0
29-Feb	0	0	0	0						0
1-Mar	0	0	0	0	0	0	0	0		0
2-Mar	0	0	0	0			0	0		0
3-Mar	0	0	0	0			0	0	0	0
4-Mar	0	0	0	0						0
5-Mar	0	0	0	0						0
6-Mar	0	0	0	0						0
7-Mar	0	0	0	0						0
8-Mar	0	0	0	0	0	0	0	0		0
9-Mar	0	0	0	0			0	0		0

Appendix C. Table 2. Continued.

Date	Daily collection (minus morts)	Strontium marking bath			Delayed mortality test				# Voucher fry removed from test group	Daily # released
					# Held in each group		# Morts recovered			
		# Added	# Morts	# Removed	Test	Control	Test	Control		
10-Mar	1	1	0	1			0	0	0	1
11-Mar	0	0	0	0						0
12-Mar	5	5	0	5						5
13-Mar	6	6	0	6						6
14-Mar	10	10	0	10						10
15-Mar	51	26	0	26	25	26	0	0		0
16-Mar	172	172	0	172			0	0		172
17-Mar	369	394	1	393			0	0	5	414
18-Mar	630	630	0	630						630
19-Mar	1,220	1,220	0	1,220						1,220
20-Mar	586	586	0	586						586
21-Mar	498	498	0	498						498
22-Mar	950	850	0	850	100	100	0	0		750
23-Mar	1,190	1,190	1	1,189			0	0		1,189
24-Mar	1,039	1,139	0	1,139			0	0	5	1,234
25-Mar	1,215	1,215	0	1,215						1,215
26-Mar	2,072	2,072	0	2,072						2,072
27-Mar	2,799	2,799	0	2,799						2,799
28-Mar	2,372	2,372	0	2,372						2,372
29-Mar	2,145	2,045	0	2,045	100	100	0	0		1,945
30-Mar	1,104	1,104	0	1,104			0	0		1,104
31-Mar	1,546	1,646	0	1,646			0	1	5	1,740
1-Apr	1,444	1,444	0	1,444						1,444
2-Apr	2,021	2,021	1	2,020						2,020
3-Apr	1,089	1,089	0	1,089						1,089
4-Apr	899	899	0	899						899
5-Apr	1,517	1,417	0	1,417	100	100	0	0		1,317
6-Apr	1,604	1,604	0	1,604			0	0		1,604

Appendix C. Table 2. Continued.

Date	Daily collection (minus morts)	Strontium marking bath # Added	# Morts	# Removed	Delayed mortality test: # Held in each group Test	Control	# Morts recovered Test	Control	# Voucher fry removed from test group	Daily # released
7-Apr	1,248	1,348	0	1,348			0	0	5	1,443
8-Apr	1,227	1,227	0	1,227						1,227
9-Apr	641	641	1	640						640
10-Apr	872	872	0	872						872
11-Apr	476	476	0	476						476
12-Apr	419	319	0	319	100	100	0	0		219
13-Apr	1,010	1,010	0	1,010			0	0		1,010
14-Apr	1,612	1,712	2	1,710			0	0	5	1,805
15-Apr	2,184	2,184	0	2,184						2,184
16-Apr	1,920	1,920	1	1,919						1,919
17-Apr	690	690	0	690						690
18-Apr	1,200	1,200	0	1,200						1,200
19-Apr	248	148	0	148	100	100	0	0		48
20-Apr	314	314	0	314			0	0		314
21-Apr	137	237	0	237			0	0	5	332
22-Apr	147	147	0	147						147
23-Apr	86	86	0	86						86
24-Apr	54	54	0	54						54
25-Apr	90	90	0	90						90
26-Apr	82	41	0	41	41	41	0	0		0
27- Apr	2,032	2,032	0	2,032			0	0		2,032
28- Apr	119	160	1	159			0	0	5	195
Total	45,362	45,362	8	45,354	566	567	0	1	35	45,318